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# SAND AND GRAVEL RESOURCES OF THE SACRAMENTO AREA, CALIFORNIA

1975

CALIFORNIA DIVISION OF MINES AND GEOLOGY

SPECIAL REPORT 121

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Special Report 121

# SAND AND GRAVEL RESOURCES OF THE SACRAMENTO AREA, CALIFORNIA

By

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Geologist

1975

California Division of Mines and Geology
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CONTENTS

ABSTRACT ..... 5

INTRODUCTION ..... 7

GEOLOGY ..... 7

Plio-Pleistocene Rocks ..... 10

Victor Formation ..... 10

Holocene Alluvium ..... 10

Soils ..... 10

ANALYSIS OF POTENTIAL AGGREGATE DEPOSITS ..... 10

Analysis of Water Well Log Data to Locate Aggregate "Target Areas" ..... 12

Seismic Geophysical Testing in the Elk Grove Area ..... 15

Rapid Field Appraisal of Aggregate Potential of Folsom-Sacramento Dredge Tailings ..... 16

Laboratory Analyses of Seven Large Samples of Plio-Pleistocene Tailings ..... 17

ESTIMATION OF THE SAND AND GRAVEL RESOURCES ..... 22

ECONOMICS OF THE AGGREGATE INDUSTRY ..... 31

Demand ..... 31

Production ..... 31

Costs and Prices ..... 32

SUMMARY AND RECOMMENDATIONS ..... 34

REFERENCES ..... 34

## ILLUSTRATIONS


Figure 1. Sand and gravel production in Sacramento County ..... 8

Figure 2. Location map of the Sacramento area ..... 9

Figure 3. Schematic section through the American River area ..... 11

Figure 4. Gravel distribution map, 50 to 40 foot interval ..... 13

Figure 5. Gravel distribution map, 40 to 30 foot interval ..... 13

Figure 6. Gravel distribution map, 30 to 20 foot interval ..... 13

Figure 7. Gravel distribution map, 20 to 10 foot interval ..... 13

Figure 8. Gravel distribution map, 10 to 0 foot interval ..... 14

Figure 9. Gravel distribution map, 0 to -10 foot interval ..... 14

Figure 10. Composite gravel distribution map, 50 to 20 foot interval ..... 14

Figure 11. Composite gravel distribution map, 20 to -10 foot interval ..... 14

Figure 12. Schematic drawing of a possible stratigraphic section of the Elk Grove Outlier area ..... 16

Figure 13. Schematic representation of the distribution of sediments within tailings of parts of the Folsom-Sacramento dredge field ..... 21

Figure 14. Apparent values per ton of sand and gravel sold or used in Sacramento County and approximate United States carbon steel prices ..... 33

Table 1. Aggregate test results, sample 101 ..... 23

Table 2. Aggregate test results, sample 102 ..... 24

Table 3. Aggregate test results, sample 103 ..... 25

Table 4. Aggregate test results, sample 104 ..... 26

Table 5. Aggregate test results, sample 105 ..... 27

Table 6. Aggregate test results, sample 106 ..... 28

Table 7. Aggregate test results, sample 107 ..... 29

Table 8. Sand and gravel resources of the Sacramento area ..... 30

Photograph 1. View of a housing tract in the Sacramento area ..... 8

Photograph 2. View of a gravel plant in Sacramento County ..... 8

Photograph 3. Stripping of overburden in Sacramento County ..... 11

Photograph 4. Dredge tailings sampling operation on McDonnell-Douglas property ..... 21

Photograph 5. Concrete mixer for scrubbing clay-rich aggregate samples ..... 33

Plate 1. Geologic and sample location map of the Sacramento area, scale 1:62,500 ..... 18-19

## ABSTRACT

In 1972-73 the California Division of Mines and Geology studied the aggregate resources of the Sacramento area in order to provide a more accurate inventory of aggregate resources in northern California and to aid Sacramento County in mineral resource planning. In October 1973, there were approximately 40 million tons of "permitted" aggregate reserves in the Sacramento area, or enough to supply local needs for at least six years. In addition, there were approximately 160 million tons of "tested" aggregate resources in the area, which is enough aggregate to satisfy local demand for an additional 20 to 25 years.

A rough estimate of untested resource potential, called "inferred resources", was made. The size and distribution of these inferred resources are based strictly on inferential hydrologic and geologic data. The uncertainty of the inferred resource estimates necessitates that they not be used to compute mineral depletion dates. For planning purposes, it is safe to assume that 250 million tons of inferred resources might yet be discovered in the Florin-Perkins area, provided that certain steps are taken by the County government to control housing and commercial development in the area.

Sand and gravel tonnages were computed on the basis of 1973-74 economic factors and the assumption that a 50-foot wide buffer zone would be required by the County for environmental reasons.

If past production is indicative of future aggregate demand, then it appears that future aggregate demand in the Sacramento area will increase less than 2 percent annually. Prices of aggregate products will probably increase at a rate commensurate with general inflation, and perhaps at a higher rate if the market becomes totally dominated by one or two companies.

Economically important deposits of sand and gravel in the Sacramento area are restricted almost entirely to the Pleistocene Victor Formation or dredge tailings derived from the Victor Formation. The presumption that nearly limitless supplies of aggregate materials lie in the Folsom-Sacramento dredge field is not true. Significant percentages of unsound rock materials and clay in these alluvial tailings make as much as three-quarters of the vast Folsom-Sacramento field unusable under current economic conditions. Although Sacramento County has sufficient tested aggregate resources and reserves for 30 years or more, detailed resource planning is necessary to insure the wisest use of valuable mineral lands.

# *Sand and Gravel Resources of the Sacramento Area, California*

By John S. Rapp

## INTRODUCTION*

Approximately 6 million tons of sand and gravel are produced in Sacramento County each year. Three large companies produce about 80 percent of the total. Most of this sand and gravel is used for aggregate in the construction of highways, public utility structures, and buildings. Two of the major producers, Teichert Aggregates and Granite Construction Company, are mining sand and gravel from slightly elevated terraces of the Pleistocene Victor Formation in an area about 10 miles southeast of downtown Sacramento. Lone Star Industries, Inc., formerly Pacific Coast Aggregates, is producing aggregate from dredge tailings near the American River at Sunrise Boulevard (plate 1). The remainder of Sacramento County's aggregate production comes from a number of smaller producers.

In the eastern and midwestern parts of the United States, and to a lesser extent in California, manufactured sand and crushed rock is used for construction aggregate. Volcanic cinder and thermally expanded shale are used for aggregate in special lightweight concrete structures and bricks. However, in terms of value and tonnage, natural sand and gravel is by far the most important mineral aggregate in California and is the only aggregate used in Sacramento County for general construction purposes.

Aggregate is used primarily as a filler for Portland Cement and asphaltic concretes and as a base material in construction. There are several grades of aggregate, each with its own formal specifications. State and Federal specifications generally pertain to the particle distribution of the aggregate mixture, and the physical and chemical properties of the constituent mineral clasts.

Because the physical and chemical properties of an aggregate ultimately dictate the strength and durability of a concrete made from it, strict specifications regarding soundness and durability of aggregate materials have been formulated. One such measure of aggregate soundness is the so-called "fine durability index", No. California 229, of the California Department of Transportation. This test was used many times in the course of this study because it is easy to perform, is inexpensive, and yields meaningful results in a relatively short period of time. Most of the tailings of the Folsom-Sacramento dredge field fail to meet "fine durability index" specifications for concrete aggregate and base materials.

The California Division of Mines and Geology is obligated to help prevent the loss of irreplaceable mineral deposits as a result of sporadic urban development. Sacramento County was selected from a number of "mineral problem areas" for two reasons: (1) large deposits of alluvium were known to exist in the county, and (2) detailed commercial aggregate test data were reportedly available upon request. Furthermore, it was known that urban land development had resulted in the loss of aggregate resources in the Sacramento area.

The technical work for this project was done in two parts. The first part involved the investigation of in situ gravel deposits and the compilation of subsurface data. The second part involved prospecting and detailed testing of tailings of the Folsom-Sacramento dredge field. Virgin gravel beds and dredge tailings were studied separately because of distinct differences in their physical character and accessibility for sampling. Most of the aggregate and concrete testing was done at Teichert Aggregates' laboratory, which was phased out by the company in 1974.

Technical reports and maps were contributed for use in this project by nearly every company and governmental agency having knowledge of the area. Data from the following organizations were used in preparing this report: Arden Sand and Gravel Company, Granite Construction Company, Lone Star Industries, Inc., McDonnell-Douglas Astronautics Corp., Natomas Company, Teichert Aggregates Company, Guy F. Atkinson, Contractor, California Department of Transportation, California Department of Water Resources, County of Sacramento, U. S. Army Corps of Engineers, U. S. Bureau of Land Management, U. S. Bureau of Mines, U. S. Bureau of Reclamation.

## GEOLOGY

Sedimentary rocks of the Sacramento area can be divided into three basic units in order to simplify the rather complex stratigraphic picture of the area. The oldest rocks are of Plio-Pleistocene age. Several attempts have been made to subdivide the Plio-Pleistocene rocks into formational units, but, for the purpose of this study, they are considered to be a single rock type. Overlying the clay-rich sedimentary beds of the Plio-Pleistocene are younger, less weathered,

*This report was completed in late 1973 and economic statistics which might have been compiled since that time were not used to update graphs and economic projections. The oil embargo of winter 1973-74 and subsequent economic events have affected the construction industry and other important facets of the economy. It may be best to exclude economic statistics from 1974 because these figures may not be indicative of either short-term or long-term economic trends. An obvious trend may appear in the late seventies.

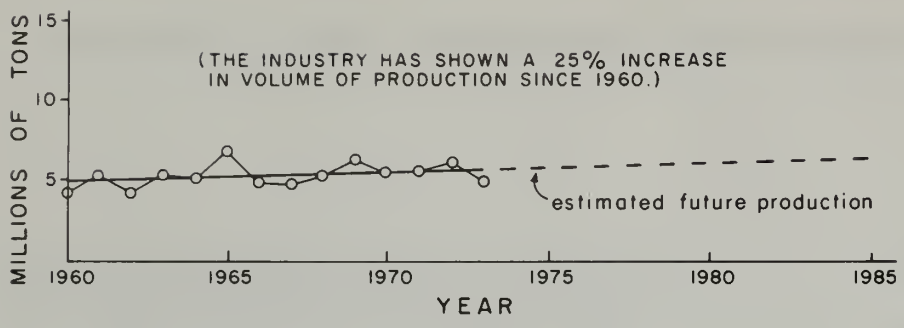
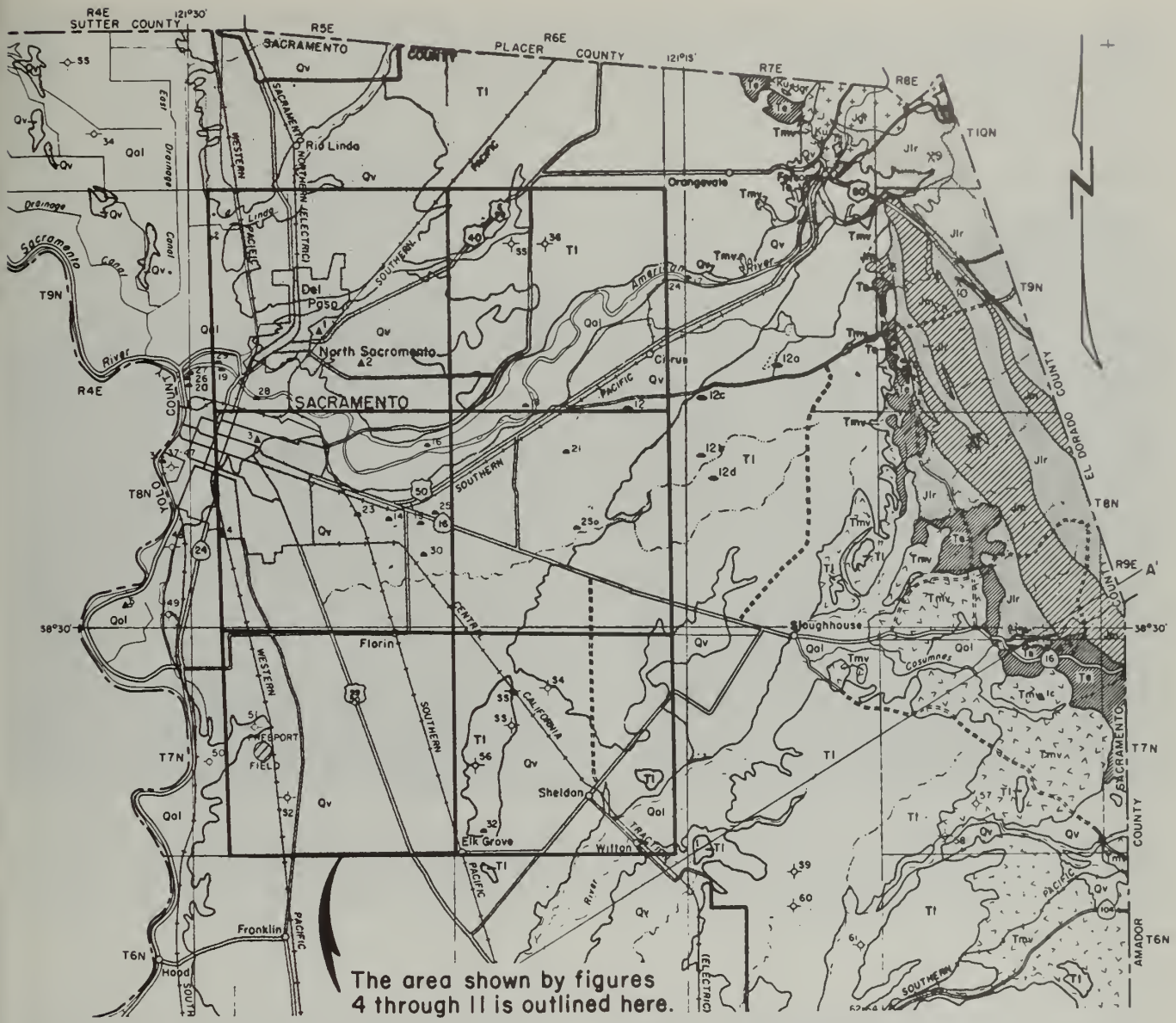



Figure 1. Sand and gravel production in Sacramento County, 1960-1973.

Photograph 1. View of a housing tract in the Sacramento area. The owners of the homes visible through the trees and other local residents have applied considerable pressure on the County of Sacramento to eliminate the gravel plant. However, the gravel plant owner owns the plant property and was producing gravel at this location long before residential development of the surrounding area was allowed. This is the crux of the sand and gravel resource problem in Sacramento County and throughout much of California.

Photograph 2. View of a gravel plant in Sacramento County. Because most sand and gravel plants produce a good deal of noise, dust, and traffic, they have become very unpopular neighbors. This photo was taken from the backyard of one of the houses in photograph 1. The disposition of the property on which the plant sits and the fate of the gravel plant have yet to be decided in court. These facts may have been overlooked by the realtor who sold the houses in photograph 1.



MAP SYMBOLS

- Holes drilled for gas
- Gas fields
- Clay
- Lode mines-gold
- Gold dredges
- Drift mines-gold
- Sand and gravel

0 2 4 6
SCALE IN MILES

Figure 2. Location map of the Sacramento area.
*From Carlson, 1955.*

EXPLANATION

| | | PATTERN SYMBOL | FORMATION | |
|---|---|---|---|---|
| QUATERNARY | Recent | | Qal | Alluvium |
| | Pleistocene | | Qv | Victor formation, river deposits of sand, silt and gravel. |
| TERTIARY | Pliocene(?) | | Tl | Laguna formation and Arroyo Seca gravel. River deposits of sand, gravel and clay. |
| | Miocene | | Tmv | Mehrten formation; water-laid andesitic material. Valley Springs formation; rhyolitic tuff, clay and conglomerate |
| | Eocene | | Te | Ione formation; quartz-anauxite sandstone and clay. Mostly non-marine. Includes some marine Eocene. |
| CRETACEOUS | Upper | | Ku | Upper Cretaceous greenish fossiliferous sandstone. Some conglomerate and siltstone. Marine. |
| JURASSIC | Upper | | Jm | Mariposa slate, minor sandstone and conglomerate. Marine. |
| | | | Jlr | Lagtown Ridge formation. Amphibolite and chlorite greenstones and schists derived from andesitic flows, tuffs and agglomerates. |
| | Jurassic | | Jgr | Granodiorite and other granitic rocks |

Pleistocene beds. These overlying sediments, referred to as Victor Formation, were named in 1939 by Piper *et al.* Younger still than the Victor Formation are Holocene gravels of the present course of the American River (figure 2).

### Plio-Pleistocene Rocks

Plio-Pleistocene rocks of the American River fan are extremely variable in texture and composition and resemble sections of older units such as the Mehrten Formation (Piper *et al.*, 1939). The American River dissected the widespread Plio-Pleistocene sediments during Pleistocene glacial episodes and subsequently filled the newly formed valley with late Pleistocene sediments of the Victor Formation. Plio-Pleistocene sedimentary rocks are typically clay-rich, poorly sorted, and laterally discontinuous. These beds of conglomerate and clay are exposed throughout eastern Sacramento County.

The Plio-Pleistocene alluvium of the American River fan assumes much of the lithologic character of the eroded source rocks. The American River transects rocks of many sorts and has done so throughout Late Tertiary time. The parent rocks include silicic and mafic igneous rocks, foliated and hornfelsic metamorphic rocks, and several types of sedimentary rocks. Consequently, sediments of the American River fan vary considerably in texture and composition from one locality to the next. It is impossible to predict with certainty the exact nature of these sediments at depth or at locations more than a few feet from any given drill hole or excavation. However, one fairly consistent sedimentary feature of the Plio-Pleistocene rocks is their tendency to be highly weathered and deficient in sand sized particles. The abundance of clay and lack of sand makes Plio-Pleistocene alluvium a poor source for commercial aggregate. Specific test results are discussed later.

### Victor Formation

The late Pleistocene Victor Formation, which unconformably overlies Plio-Pleistocene sedimentary rocks, was deposited by the American River over a broad alluvial fan. The valley formed by the American River during glaciation was largely "backfilled" with Victor alluvial sediment. The Victor Formation is composed of unweathered crystalline rocks of the Sierra Nevada and reworked Tertiary rock. Fluvial abrasion has removed much of the unsound, weathered rock and clay from the reworked Plio-Pleistocene sediments. Consequently, the Victor Formation is composed largely of clean and durable crystalline rocks that provide good aggregate materials.

Known sand and gravel deposits of economic importance within the Sacramento area are restricted to the Victor Formation or dredge tailings derived from the Victor. Extensive records of the U. S. Army Corps of Engineers and the California Department of Transportation indicate that sediments of the Victor Formation are generally durable, non-absorptive, and fairly clean. Although the Victor Formation is a good aggregate source, it is not consistently high in quality throughout. There are "oxbow wedges" and irregularly shaped lenses of buried alluvium within the formation that contain soft, porous materials and excessive quantities of clay.

The most widely accepted geologic explanation of the stratigraphy of the Sacramento area was introduced by Roy Shlemon in 1972. Shlemon believes that the Victor Formation, which he refers to as the Riverbank Formation, can be differentiated into two distinct units, namely the younger and older Riverbank Formation. The distinction of units within the late Pleistocene is based upon sedimentary lithologies, age dating, and the alleged subsurface consistency in the distribution of characteristic rock types. However, in viewing late Pleistocene rocks of the Sacramento area as an aggregate source rather than from the stratigraphic viewpoint, the late Pleistocene beds can be treated collectively. Clay beds and alluvium with abundant "soft rock" are present nearly at random within the stratigraphic section. These sporadic bodies of objectional material, which resemble older Plio-Pleistocene rocks, were probably derived from the erosion of older terraces.

### Holocene Alluvium

Holocene river gravels from the latest stage of sedimentation in the American River Valley lie within the present bed of the river and are similar in character to sediments of the Victor Formation. Holocene alluvium provides a premium aggregate material because of its soundness, lack of compact clay, and accessibility for mining. However, Holocene alluvium is not generally available for mining because it lies within environmentally sensitive riparian areas that are reserved for recreation.

### Soils

Soils of the Florin-Perkins to Folsom area, where most of Sacramento's aggregate resources lie, range from sandy loam to clay depending largely upon the underlying sedimentary units. Much of the soil that overlies rocks of Plio-Pleistocene age are deficient in sand and loam and are therefore of little agricultural value. Soils that overlie the Victor Formation vary considerably in composition but are often found to be more sandy and less clayey. Soils in the Sacramento area vary in thickness from about 3 to 15 feet and are considered overburden by aggregate producers.

## ANALYSIS OF POTENTIAL AGGREGATE DEPOSITS

The area between downtown Sacramento, Folsom, State Highway 50, and Interstate Highway 80 has undergone extensive residential and commercial development. Elements of the Sacramento County General Plan indicate that future growth is

Photograph 3. Stripping of overburden in Sacramento County. Strip mining is not restricted to the coal industry. Sand and gravel is usually mined by stripping. The above photograph shows two "scrapers" and three "bull dozers" in the process of stripping overburden, consisting of clayey soil, at the Granite Construction Company pit in the Perkins area. A 5 to 10 foot soil horizon is being removed in order to expose 30 feet of high quality sand and gravel. The soil is being transported to a stockpile where it will be stored until needed for reclamation of the mined land. The clayey soil is of no use as an aggregate.

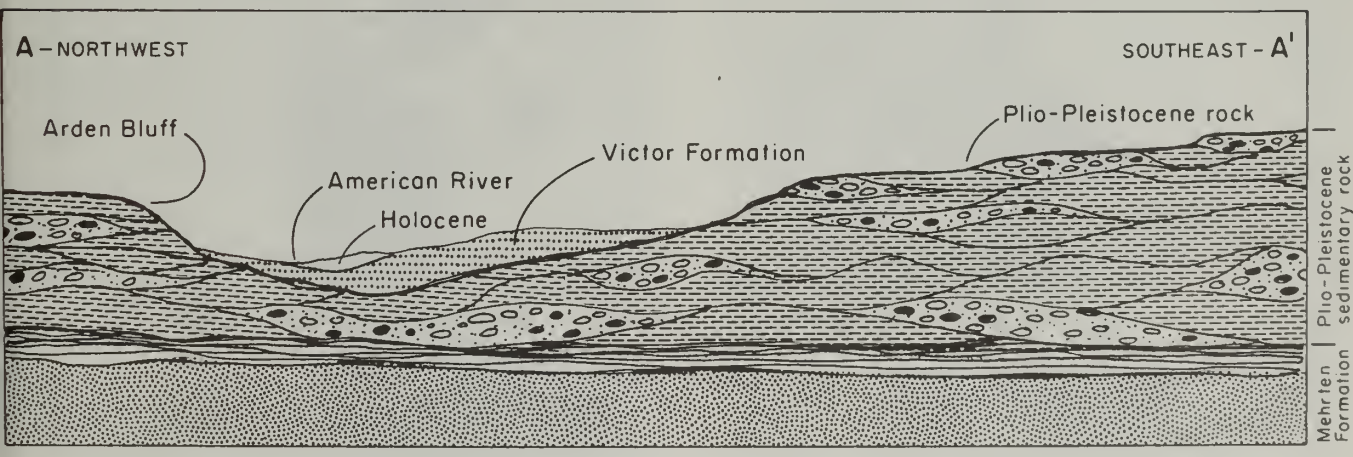



Figure 3. Schematic section through the American River area. Location of cross-section shown on plate 1.

expected in this area. This part of Sacramento County comprises about 30 percent of the total county area and was excluded from further consideration as a potential aggregate source area.

In addition, highway, street, railroad, canal, and utility rights-of-way and the protected river lands exclude narrow strips of land throughout the county. The eastern part of Sacramento County is underlain by rocks that cannot be processed into concrete-grade aggregate under current economic conditions. Soils and sediments of the delta region are typically deficient in sand and high in organic matter and clay. Areas west of the Central California Traction Railroad tracks typically have thick clayey soil horizons and sedimentary rocks below the surface and are generally more clayey. For these reasons, the potential commercial sand and gravel resource areas of the county seem to be restricted to the triangular-shaped area northwest of the Plio-Pleistocene lithologic contact with the Victor Formation and south of State Highway 50 (figure 2). The western boundary is approximately the Central California Traction Railroad tracks. The potential aggregate resource area includes a large part of the Folsom-Sacramento dredge tailings because the dredges used within this resource "triangle" dug to a relatively shallow depth and did not disturb the underlying Plio-Pleistocene rocks or the Mehrten Formation.

## Analysis of Water Well Logs to Locate Aggregate Resource "Target Areas"

One of the primary goals of the Sacramento aggregate resource project was to locate areas of aggregate potential that would be target areas for further investigation by the County and local aggregate producers. County planners need to know where future aggregate materials might be found in order to make effective land use decisions and formulate zoning policies with respect to land and resources development. It is equally important to know where gravel will be found as it is to know where gravel will not be found. This double concept allowed the California Division of Mines and Geology to develop useful data without having the means for conventional exploration.

The California Department of Water Resources Bulletin 118-3, published in 1974, describes the water resources and hydrology of Sacramento County. I used the information contained in approximately 3000 drillers' logs, which were compiled by the California Department of Water Resources for Bulletin 118, to delineate sand and gravel resource areas. Ground water yields at various prescribed elevations throughout the county were indicated symbolically on computer maps with one of four possible symbols, each symbol representing a certain relative yield. Maps with vertical intervals of 10 feet were used by the California Division of Mines and Geology to select potential aggregate resource areas. The computer format of the California Department of Water Resources (CDWR) program assigned a single "yield symbol" to each 10-foot interval according to the dominant lithology of that particular 10-foot section of the drill record, even if that lithology represented only half of the total 10-foot section. Certain assumptions were made in order to use the CDWR hydrologic data to delineate aggregate resource areas.

Specific yield is largely a function of permeability, which is dependent upon the rock type or sand and gravel mix of the aquifer. The symbols used by the California Department of Water Resources to denote high yield were assumed, for the purpose of this aggregate study, to represent loosely packed sand and gravel, the most suitable potential aggregate material. The symbol that indicated the lowest yield on the CDWR maps was assumed to represent clay, which is relatively impermeable and of no aggregate value. Symbols that represented intermediate yields were assumed to indicate the presence of silt, sand, and other mixed sediments. The 3000 well logs were treated collectively, thereby negating some of the inaccuracies inherent in most drillers' logs.

Assuming that specific yield can be used to estimate sedimentary rock types, computer maps above the -10-foot elevation were used to delineate apparent gravel beds and to draw contoured "gravel distribution maps" (figures 4 through 11). Areas of these contoured gravel distribution maps thought to consist of gravel and sand were enclosed in contours, as were areas where only clay was assumed to exist. Areas thought to consist of a mixed assemblage of sedimentary rocks were not enclosed. It was assumed that areas of mixed lithologies were not as likely to contain commercial deposits of sand and gravel as areas underlain by sand and gravel. Similarly, areas of low permeability thought to consist of clay were assumed to be extremely poor target areas. Portions of the county where the density of water wells was less than four wells per square mile were not contoured.

It was assumed that deposits with economic potential would more likely be present in areas where several gravel beds overlapped. Commercial deposits of sand and gravel in Sacramento County have historically had ore-to-waste ratios greater than 2 to 1. During this study, composite maps were made by superposing the gravel distribution maps three at a time. These composite maps indicate points where thicknesses of gravel might be 20 or 30 continuous feet. The composite maps were used to estimate "inferred resources" and define target areas for future exploration (figures 10 and 11). These maps also tend to substantiate surface observations that alluvial units throughout the county are extremely variable, both vertically and laterally, in texture and composition.

The gravel distribution maps (figures 4 through 11) suggest that an array of overlapping gravel beds stretches from Perkins Junction to the Plio-Pleistocene terraces near Gerber Road (plate 1). Nearly all the apparent sand and gravel deposits lie to the northeast of the Central California Traction Railroad tracks. The highly permeable and porous

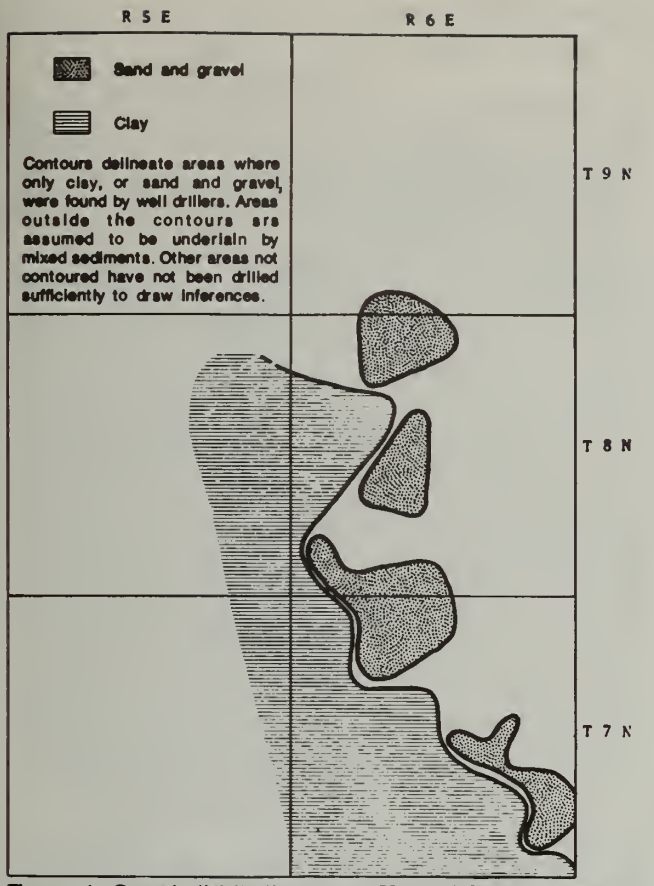

R 5 E
R 6 E
Sand and gravel
Clay
Contours delineate areas where only clay, or sand and gravel, were found by well drillers. Areas outside the contours are assumed to be underlain by mixed sediments. Other areas not contoured have not been drilled sufficiently to draw inferences.
T 9 N
T 8 N
T 7 N

Figure 4. Gravel distribution map, 50- to 40-foot interval. For location of sampled area, see figure 2.

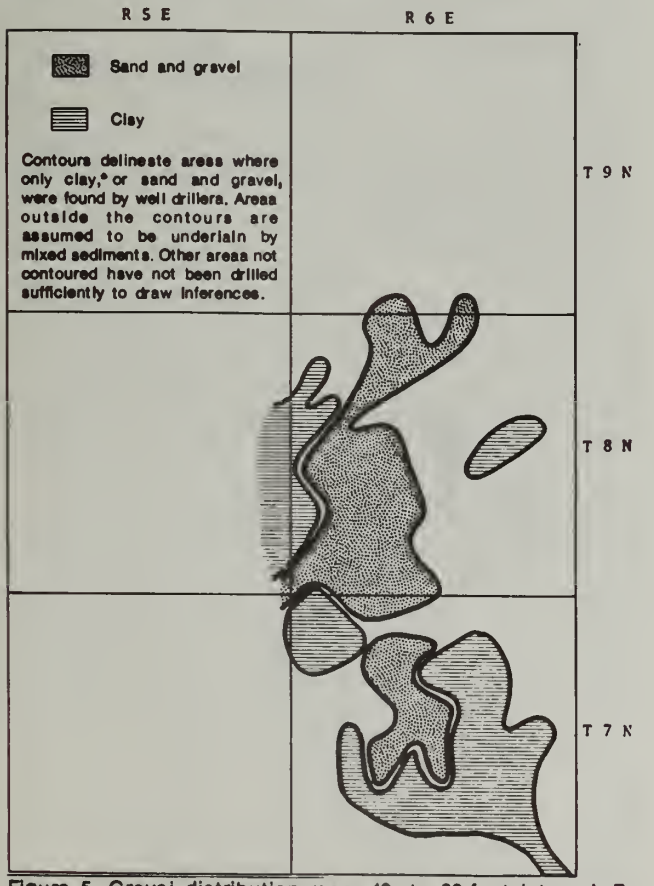

R 5 E
R 6 E
Sand and gravel
Clay
Contours delineate areas where only clay, or sand and gravel, were found by well drillers. Areas outside the contours are assumed to be underlain by mixed sediments. Other areas not contoured have not been drilled sufficiently to draw inferences.
T 9 N
T 8 N
T 7 N

Figure 5. Gravel distribution map, 40- to 30-foot interval. For location of sampled area, see figure 2.

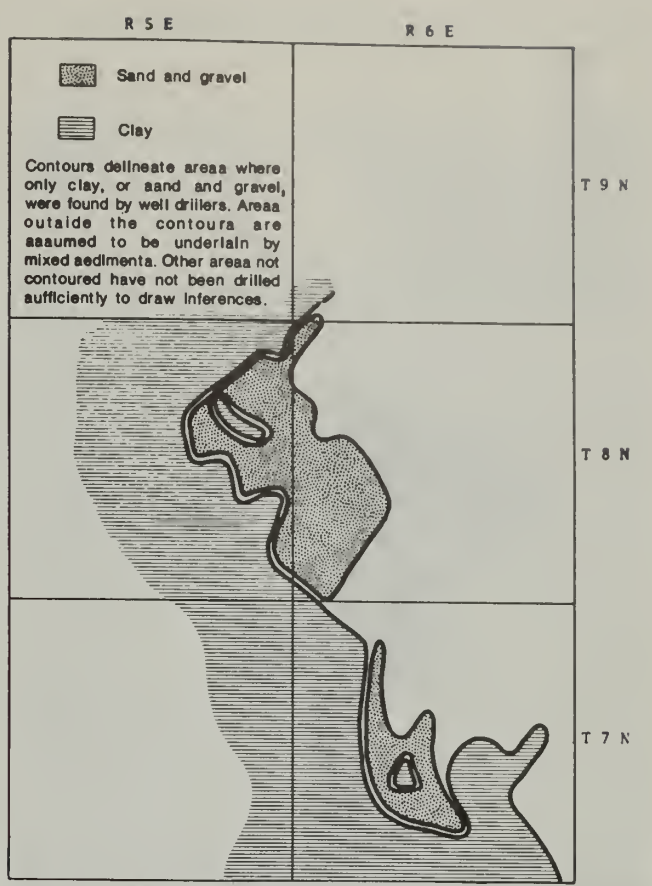

R 5 E
R 6 E
Sand and gravel
Clay
Contours delineate areas where only clay, or sand and gravel, were found by well drillers. Areas outside the contours are assumed to be underlain by mixed sediments. Other areas not contoured have not been drilled sufficiently to draw inferences.
T 9 N
T 8 N
T 7 N

Figure 6. Gravel distribution map, 30- to 20-foot interval. For location of sampled area, see figure 2.

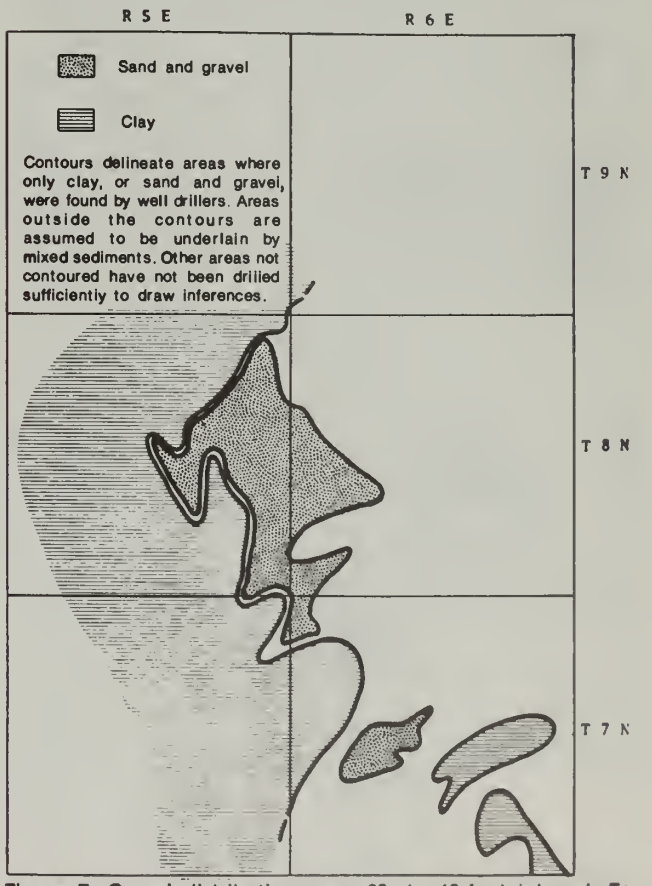

R 5 E
R 6 E
Sand and gravel
Clay
Contours delineate areas where only clay, or sand and gravel, were found by well drillers. Areas outside the contours are assumed to be underlain by mixed sediments. Other areas not contoured have not been drilled sufficiently to draw inferences.
T 9 N
T 8 N
T 7 N

Figure 7. Gravel distribution map, 20- to 10-foot interval. For location of sampled area, see figure 2.

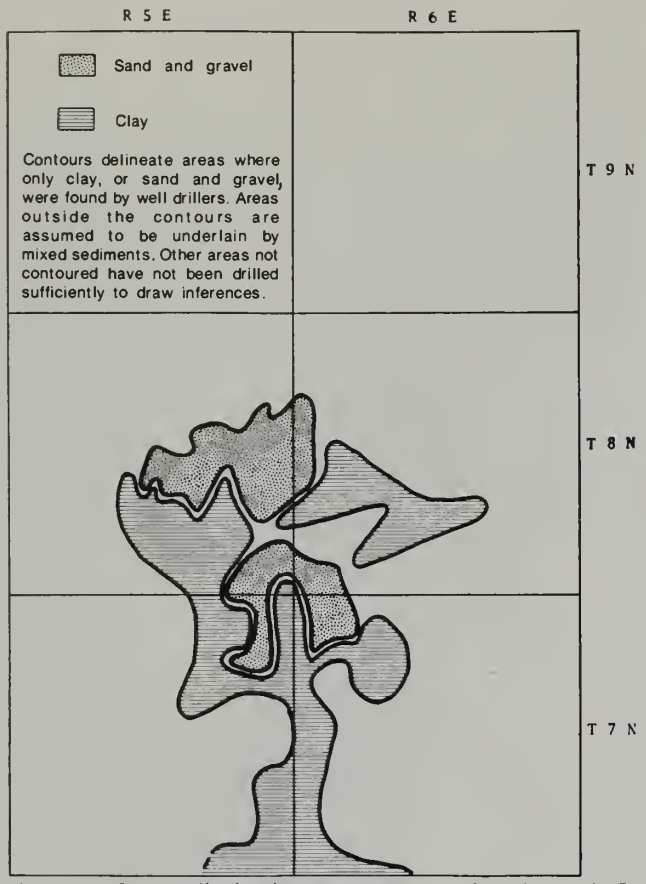

R 5 E
R 6 E
Sand and gravel
Clay
Contours delineate areas where only clay, or sand and gravel, were found by well drillers. Areas outside the contours are assumed to be underlain by mixed sediments. Other areas not contoured have not been drilled sufficiently to draw inferences.
T 9 N
T 8 N
T 7 N

Figure 8. Gravel distribution map, 10- to 0-foot interval. For location of sampled area, see figure 2.

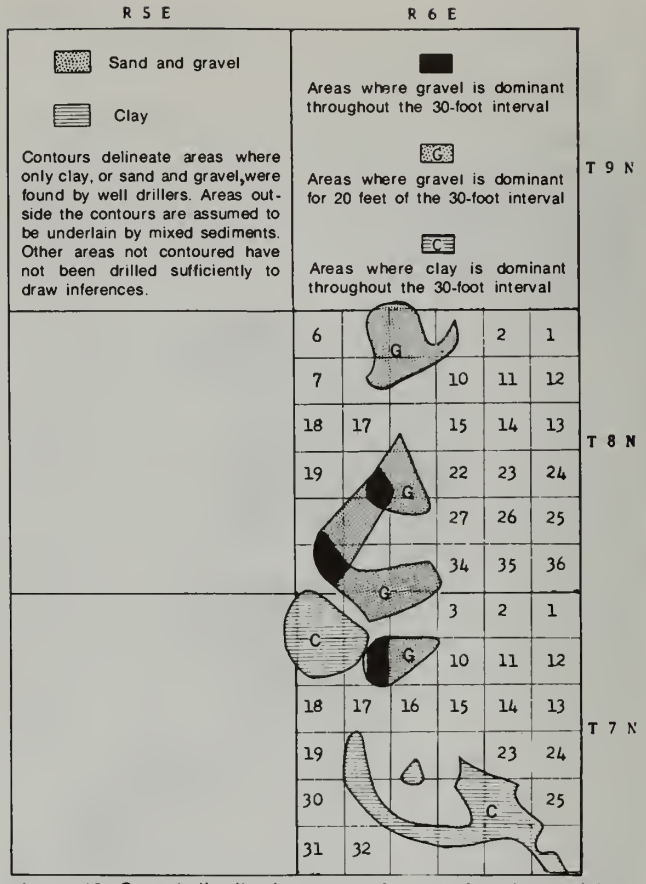

R 5 E
R 6 E
Sand and gravel
Clay
Contours delineate areas where only clay, or sand and gravel, were found by well drillers. Areas outside the contours are assumed to be underlain by mixed sediments. Other areas not contoured have not been drilled sufficiently to draw inferences.
Areas where gravel is dominant throughout the 30-foot interval
G
Areas where gravel is dominant for 20 feet of the 30-foot interval
C
Areas where clay is dominant throughout the 30-foot interval
T 9 N
T 8 N
T 7 N

Figure 10. Gravel distribution map, 50- to 20-foot interval (composite). For location of sampled area, see figure 2.

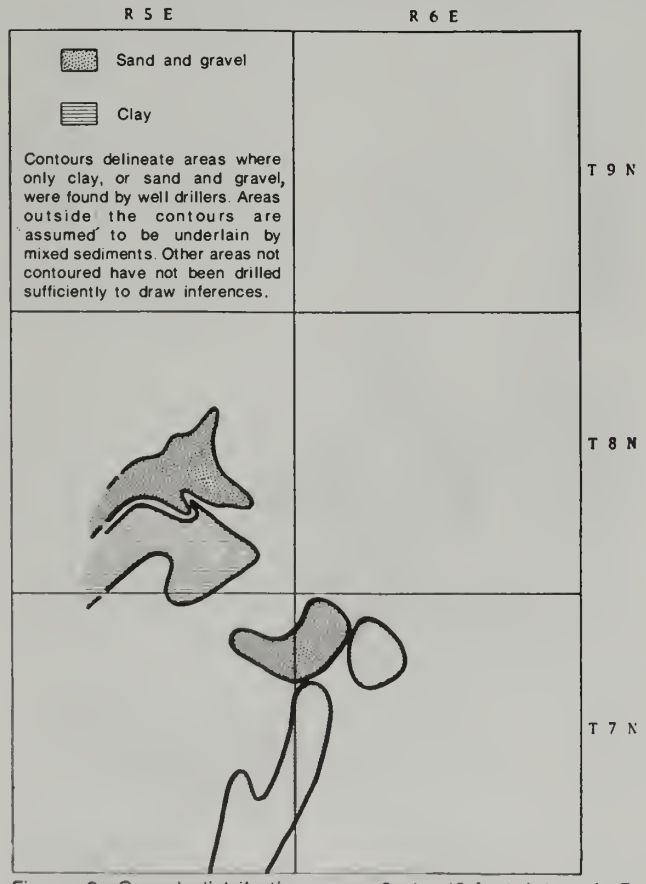

R 5 E
R 6 E
Sand and gravel
Clay
Contours delineate areas where only clay, or sand and gravel, were found by well drillers. Areas outside the contours are assumed to be underlain by mixed sediments. Other areas not contoured have not been drilled sufficiently to draw inferences.
T 9 N
T 8 N
T 7 N

Figure 9. Gravel distribution map, 0- to -10-foot interval. For location of sampled area, see figure 2.

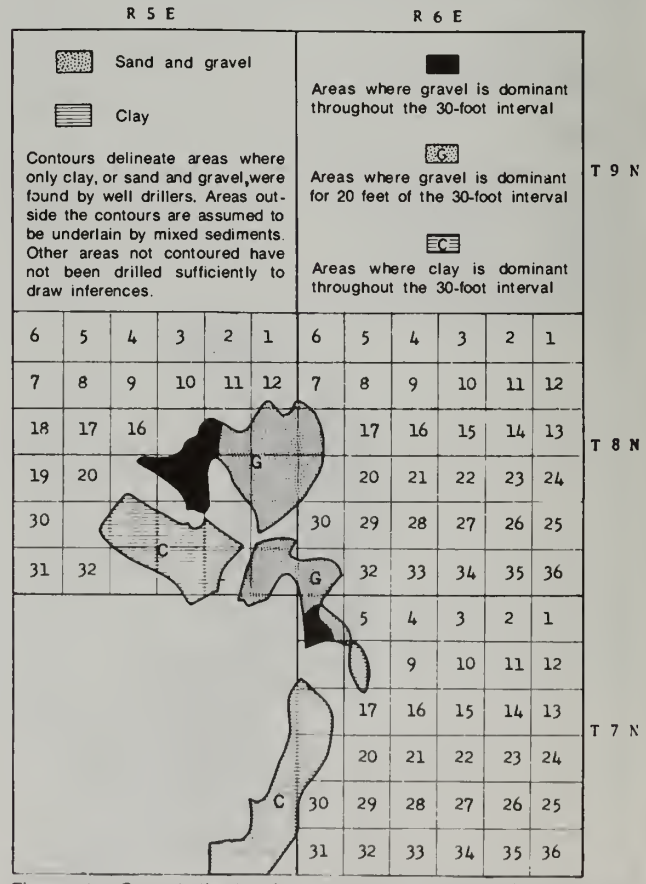

R 5 E
R 6 E
Sand and gravel
Clay
Contours delineate areas where only clay, or sand and gravel, were found by well drillers. Areas outside the contours are assumed to be underlain by mixed sediments. Other areas not contoured have not been drilled sufficiently to draw inferences.
Areas where gravel is dominant throughout the 30-foot interval
G
Areas where gravel is dominant for 20 feet of the 30-foot interval
C
Areas where clay is dominant throughout the 30-foot interval
T 9 N
T 8 N
T 7 N

Figure 11. Gravel distribution map, 20- to -10-foot interval (composite). For location of sampled area, see figure 2.

alluvium, assumed here to be sand and gravel, appears to lie at progressively lower elevations as the array of deposits is followed to the northwest. The ground elevation also drops steadily from Gerber Road northwest to Perkins Junction.

Inferential data cannot be used to evaluate mineral properties without substantial supporting data. Reserve estimates were not made for this report strictly on the basis of the water well data analysis, but some important target areas were located. A rough estimate was made of the amount of sand and gravel which may be mined from the Florin-Perkins area. This inferred resource statement should not be used for detailed economic studies or to estimate depletion dates. The estimates are sufficiently accurate to be used within the scope of broad-based planning studies. The following discussion describes one specific aspect of the well log analysis which appears to be inconsistent with the overall pattern of gravel distribution in the Sacramento area. The problem presented here is typical of geologic problems that often prevent an investigator from making inclusive statements with respect to mineral reserves without the benefit of copious detailed information.

## Seismic Geophysical Testing in the Elk Grove Area

Analyses of California Department of Water Resources water well data and gravel distribution maps derived from these data suggested the existence of an isolated sand and gravel deposit in the area south of Gerber Road at Bradshaw (figure 10 and plate 1). A 30-foot section of permeable, late Pleistocene alluvium in this area seemed geologically inconsistent with surface rock exposures.

The relatively flat-lying Plio-Pleistocene rocks of Sacramento County generally dip slightly to the southwest. There is, however, an isolated exposure of Plio-Pleistocene rock referred to as the Elk Grove Outlier, immediately west of the previously mentioned apparent sand and gravel deposit. The Elk Grove Outlier can be explained geologically in two ways. In each case, the existence of an adjacent buried permeable alluvial deposit seems rather unlikely.

The outlier may be separated from the main body of Plio-Pleistocene rock because of its inherent erosional resistance. It is difficult to visualize the erosion of a relatively small area of Plio-Pleistocene rocks to a depth 40 feet lower than adjacent outcrops of similar rock. On the other hand, the outlier may be the result of uplift of the southwest block of a northwest-trending fault. A northwest-trending lineament can be easily traced on aerial photos and topographic maps from the American River to the Cosumnes River. This lineament forms the eastern contact of Plio-Pleistocene rocks of the Elk Grove Outlier and the late Pleistocene Victor Formation. Similar northwest-trending lineaments exist in other areas of the eastern San Joaquin and Sacramento Valleys. The lineament is here referred to as the Central California Traction Railroad (CCTR) lineament because of its proximity to railroad tracks of the same name (plate 1).

The CCTR lineament can be recognized from the ground in some areas because of shallow topographic depressions and the alignment of intermittent streams. If, as mentioned previously, the Elk Grove Outlier was formed by minor uplift of Plio-Pleistocene rocks to the southwest, projection of Plio-Pleistocene bedding would indicate that overlying late Pleistocene Victor sediments should be no more than 20 feet thick at the eastern terminus of the outlier. However, ground water data suggest the existence of about 30 or 40 feet of permeable alluvium, which implies the existence of late Pleistocene Victor Formation or unusually permeable Plio-Pleistocene rock.

Two attempts were made to determine the thickness of surficial sediments with seismic geophysical testing equipment. Both a pocket seismograph and a 12-channel refraction seismograph failed to yield meaningful results. Heterogeneity of subsurface units, or possible inadequate signal energy, resulted in both early and late arrivals. It appeared that laterally discontinuous clay beds with moderate seismic "velocities" were intercalated with "slower velocity" sand and gravel units. True depths were not determined because seismic signals could not be transmitted through the entire section to the base of the Victor Formation and back to the surface.

The limited seismic work that was done, primarily by Gordon W. Chase and William M. Wells, suggests that the seismic velocity of Plio-Pleistocene rocks in the Elk Grove Outlier area is about 3200 feet per second (fps). Overlying alluvium, regardless of its age, appears to have a seismic velocity of about 2300 feet per second. Superficial material, probably a sandy loam, had a seismic velocity of from 1000 to 1400 feet per second.

In summary, it appears that the area immediately east of the Elk Grove Outlier is underlain by alluvium of mixed lithologies. The depth of permeable alluvium and potential aggregate resources associated with those rocks is not known. The depth is dependent upon several factors, including the mode of erosion, geomorphic development, and deposition of Plio-Pleistocene and Late Pleistocene alluvium.

If the geomorphology of the area has largely resulted from faulting, this faulting must have occurred since Pliocene time. The trace of the CCTR lineament was inspected in the field, but no evidence of Holocene movement was seen. The lineament marks the terminus of Plio-Pleistocene terraces in the Florin area and similar lineaments elsewhere in the Valley likewise mark the contacts of Plio-Pleistocene and late Pleistocene alluvial units (figure 12).

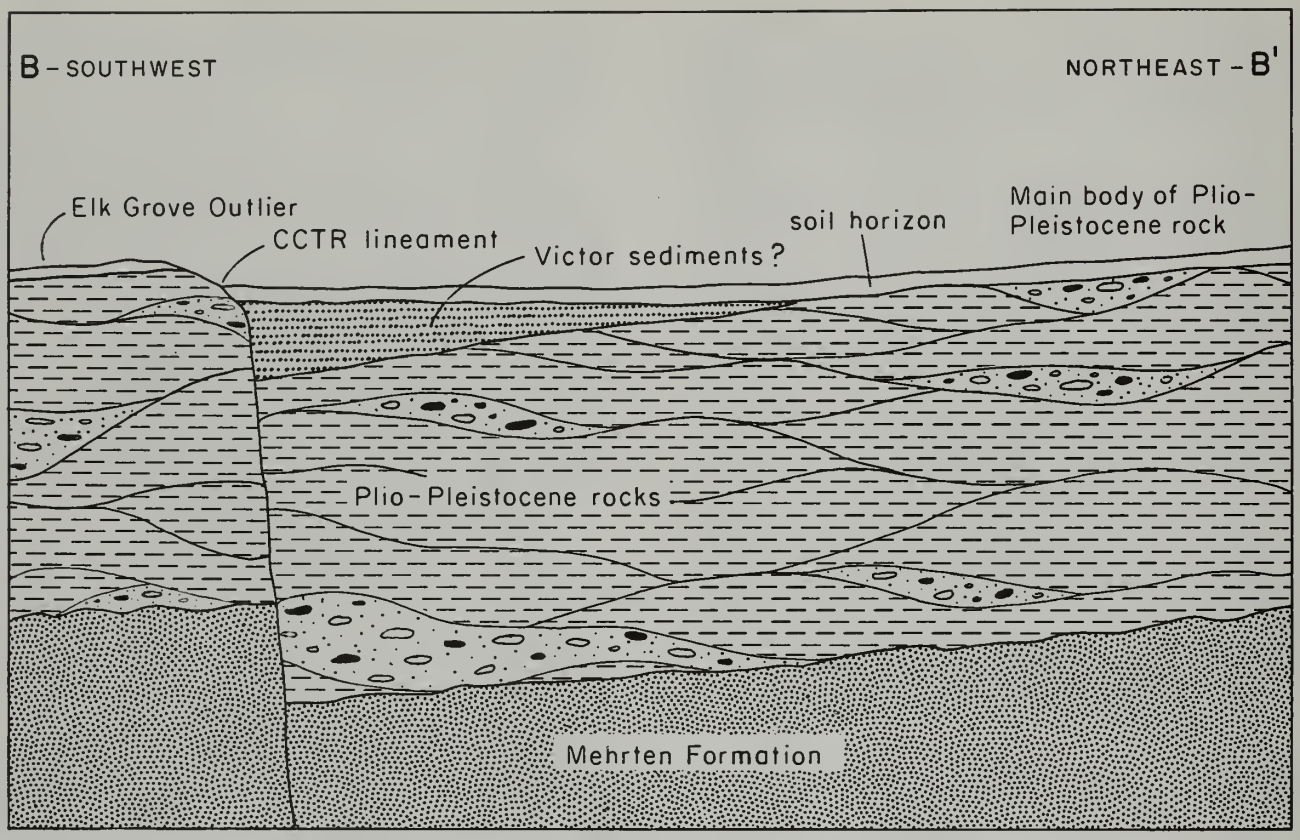



Figure 12. Schematic drawing of a possible stratigraphic section of the Elk Grove Outlier area. Location of cross-section shown on plate 1.

Hypothetical section through the Elk Grove Outlier, showing possible relative movement along the Central California Traction Railroad (CCTR) lineament. Schematic representation of late Pleistocene Victor sediments filling the gap. In reality, the outlier may be an erosional remnant resultant from differential weathering. High porosity and permeability of sediments immediately east of the outlier may not be related to the age of the rocks. The approximate seismic velocities for the geologic units shown are: Plio-Pleistocene, 3200 feet per second; Victor Formation, 2300 feet per second; and soil horizon, 1200 feet per second. The view is to the northwest, along the CCTR lineament.

## Rapid Field Appraisal of Aggregate Potential of Folsom-Sacramento Dredge Tailings

During the later part of the nineteenth century and the first half of this century, large bucket-line gold dredges were used to excavate nearly 30 square miles of elevated river terraces in the Sacramento area. The dredge operators did not restrict themselves to either the Victor or Plio-Pleistocene units, but wandered about the countryside following gold values located by preliminary drilling. During the dredging process, cobbles and gravels larger than three-eighths of an inch were generally screened from finer sand and clay and stacked in long piles over a blanket of sand-sized tailings that formed as the sandy waste was dumped over the stern of the dredge. The continuous rows of cobbles superficially resemble windrows of hay and are commonly referred to as "tailings windrows".

Whereas in situ gravel deposits of the Sacramento area are generally not accessible from the surface, potential aggregate materials of the Folsom-Sacramento dredge tailings are accessible for sampling. Also, because the dredge tailings serve essentially no useful purpose, they are readily available for use as aggregate. The dredge tailings are, therefore, important with respect to Sacramento County's mineral resource situation. One of the most important aspects of this project was to sample the Folsom-Sacramento dredge field and to determine how much of this material is usable for concrete aggregate.

Initial observations were made at 100 localities within the Folsom-Sacramento dredge field. Approximately 300 rock clasts, ranging in size from 4 mesh to 1 foot or more in width, were inspected at each locality. Clasts were selected with as little bias as possible in order to avoid collection of a disproportionate number of clasts of any given rock type. Features such as apparent porosity, hardness, strength, staining, and mineralogy were observed and noted.

Rapid field identification was adequate to recognize inherent durability problems of aggregate materials. Later laboratory analysis seemed to demonstrate that fine durability index ratings could be roughly estimated on the basis of modal examination of cobbles from the same alluvial exposure. In general, alluvium that contained more than 5 percent "unsound" cobbles, as judged by their field appearance, was of marginal commercial value in Sacramento County under current economic conditions. The distribution of "durable" and "unsound" cobbles seemed to be bimodal. In other words, clean sand and gravel deposits, such as might be found in portions of the Victor Formation, contained very few unsound cobbles, whereas the Plio-Pleistocene alluvium contained as much as 40 percent unsound cobbles but generally about 15 to 25 percent.

Initial field observations at these same 100 localities suggested that Plio-Pleistocene gravel from dredge tailings was probably unfit for use in concrete. Subsequent detailed testing at seven localities demonstrated that this material was indeed unfit for concrete use because unsound rock and excessive clay could not be effectively removed. This initial work also suggested that about three-quarters of the Folsom-Sacramento dredge tailings could not be used for concrete grade aggregate.

## Laboratory Analyses of Seven Large Samples of Plio-Pleistocene Tailings

More extensive testing clearly defined the problems of utilizing Plio-Pleistocene gravels for concrete grade aggregate. Bottom-sealing drill rigs are generally used to sample alluvial materials because they retain the alluvium sample intact, allowing the investigator to see original sedimentary features. Drilling costs with this type of equipment can range from $6.00 to $30.00 per foot, depending on drilling conditions and site location. Because the California Division Mines and Geology had neither the equipment nor the budget to drill a series of holes, arrangements were made to sample the property by other means. McDonnell-Douglas Astronautics Corp. provided CDMG with a back-hoe and operator. Teichert Aggregates provided a trailered rock screen and aggregate testing facilities. A two and a half ton truck was rented from a local agency to tow the trailered rock screen and a special towing permit was obtained from the County.

Six localities were chosen to sample dredge tailings derived from Plio-Pleistocene alluvium. These localities were widely spread over property belonging to McDonnell-Douglas Astronautics Corp. (plate 1). Three of the original localities were abandoned because of their remoteness and the difficulty in positioning sampling equipment. Four new areas that could be sampled easily were chosen instead.

In order to obtain representative samples, it was necessary to dig as deeply as possible into the tailings windrows from the side or in places where dozers had previously cut fire trails. Figure 13 is a schematic drawing of the windrows found on McDonnell-Douglas Astronautics Corp. property.

The average sample size was 2231 pounds. As the back-hoe was digging, every other bucket was cast aside in order to avoid collecting a disproportionate fraction of the sample from any one part of the hole. The back-hoe bucket was only 12 inches wide, yet few large cobbles spilled out during removal. The maximum depth attainable by the back-hoe and operator was about 10 feet, while maximum depths of the tailings varied from 80 to 100 feet from one area to another. Dredges mined sediments from 80 to 100 feet below ground surface and stacked coarse aggregate windrows on top of fine aggregate spoil. Because of the substantial depth of tailings, bottom materials were not adequately sampled.

Because of the wide variance in the distribution of sediments mined by the dredges and the mode of dredge "stacking", accurate estimates of the relative proportions of fine and coarse tailings could not be made. However, reasonably accurate estimates were made of the distribution of the particle sizes within

ARDEN-ARCADE
CARMICHAEL
FOLSOM BLVD
S.P.R.R.
COLOMA
T9N
R6E
T8N
R6E
T8N
R7E
A
A'
B
B'
HOWE AVE
FULTON AVE
WATT AVE
MARCONI AVE
EL CAMINO AVE
WHITNEY AVE
WALNUT AVE
GARFIELD AVE
ARDEN WAY
FAIR OAKS BLVD
HOFFMAN PARK
GOETHE PARK
FOLSOM BLVD
S.P.R.R.
COLOMA
U.S. ARMY SIGNAL DEPOT
PERKINS ROAD
FLORIN ROAD
GERBER ROAD
CALVINE ROAD
BRADSHAW ROAD
ELDER CREEK ROAD
MATHER AIR FORCE BASE
JACKSON HWY
EXCELSIOR ROAD
PARK SITE
SACRAMENTO COUNTY HOSPITAL
SAC. STATE COLLEGE
CAL EXPO
RIVER
FOLSOM BLVD
BROADWAY
50TH AVE.
POWER INN ROAD
C.C.C.R.R.

Plate 1

# GEOLOGIC AND SAMPLE LOCATION MAP OF THE SACRAMENTO AREA

*(Explanation on following page.)*

# EXPLANATION FOR

## GEOLOGIC AND SAMPLE LOCATION MAP OF THE SACRAMENTO AREA

Plio-Pleistocene Rock - The Laguna Formation and Arroyo Seco Gravels (Piper, *et al*, 1939), Fair Oaks Formation (Shlemon, 1967), South Fork Gravels (California Department of Water Resources, 1974), and all other undifferentiated alluvial units of Plio-Pleistocene age were grouped together because of lithologic similarity. Plio-Pleistocene alluvium is typically clay rich and contains from 15 to 40 percent unsound rock clasts. Geological contact of the Plio-Pleistocene units taken from California Department of Water Resources Bulletin 118-3.

Tailings of the Folsom-Sacramento Dredge Field

Area of appreciable aggregate resource potential

Area underlain by tested aggregate resources

Area underlain by permitted aggregate reserves

Mined aggregate resource land

## SYMBOLS

● Tailings sample locality where less than 5% of the rock clasts appeared to be unacceptable for use in Portland Cement concrete.

▲ Tailings sample locality where more than 5% of the rock clasts appeared to be unacceptable for use in Portland Cement concrete.

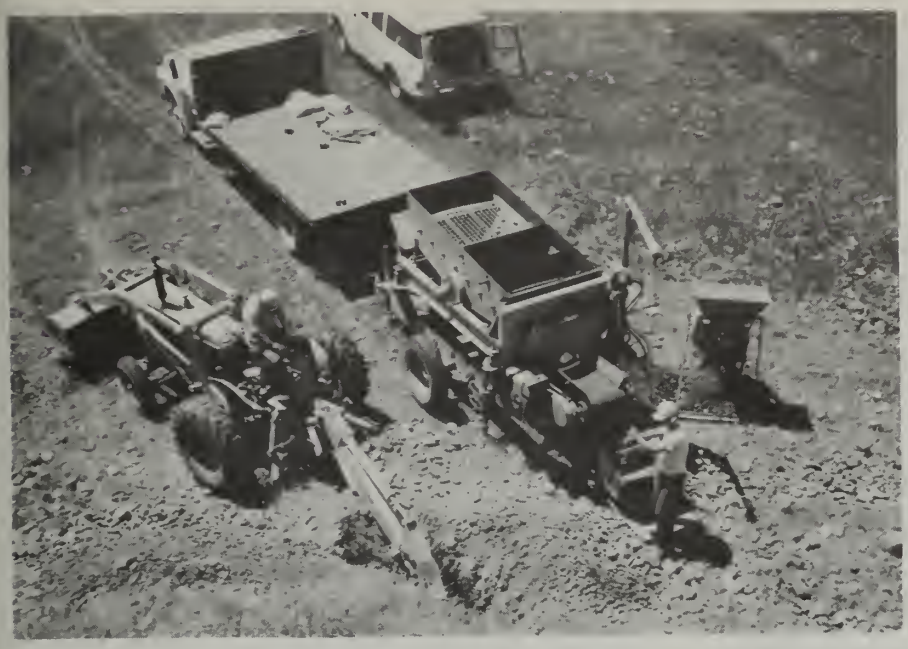
△ 101 Sample locality from which approximately 1 ton of tailings were taken and tested. See tables 1-7.

A-A′ Schematic section through the American River area.

B-B′ Schematic section through the Elk Grove Outlier.

Major sand and gravel plant.

Cultural base map from the Planning Department of Sacramento County.



Photograph 4. Dredge tailings sampling operation on McDonnell-Douglas Astronautics Corp. A backhoe was used to collect samples of tailings. Every other bucket was cast aside to prevent collecting a disproportionate amount from the top or bottom of the pit. The tailings were dumped on the forward screen where cobbles larger than 2 inches were retained. Minus 2-inch material was conveyed to the weighing bucket and collected. Gary Taylor, of the California Division of Mines and Geology, recorded sample weights. Split samples, about 82 pounds each, were placed on the flat bed truck. Note the sample splitter on the right side of the photograph and the hydraulic lift with which the weighing bucket was manipulated. Most of the sampling equipment was designed and assembled by Jim Mildren of Teichert Aggregates, who has tested aggregate materials from deposits throughout northern California.

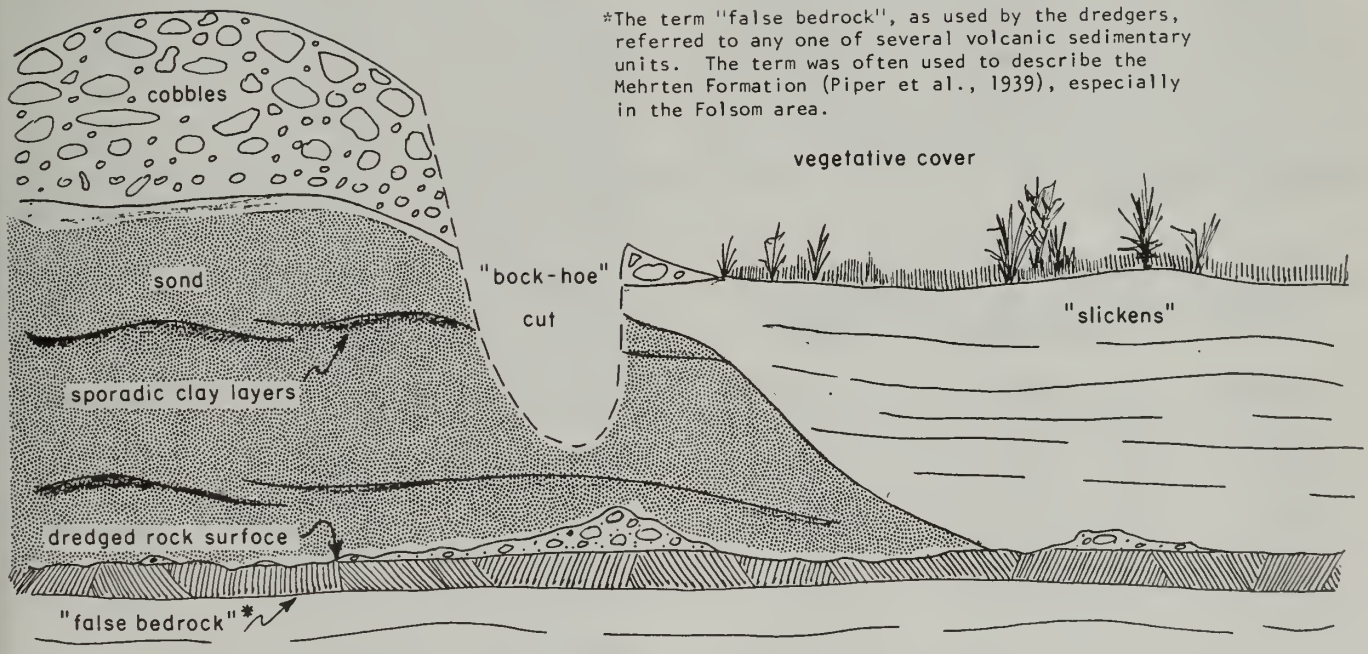

*The term "false bedrock", as used by the dredgers, referred to any one of several volcanic sedimentary units. The term was often used to describe the Mehrten Formation (Piper et al., 1939), especially in the Folsom area.
cobbles
vegetative cover
sond
"bock-hoe"
cut
"slickens"
sporadic clay layers
dredged rock surfoce
"false bedrock"*

Figure 13. The distribution of sediments in a typical tailings pile of the Folsom-Sacramento dredge field.

the coarse aggregate samples (greater than 3/8 inch) and the fine aggregate samples (less than 3/8 inch). The fine tailings were well mixed by trommels on the dredges and various sand sized particles that were dumped over the stern probably had very little time to settle differentially out of suspension in the muddy dredge pond.

All alluvium excavated by the back-hoe was dumped into a trailered rock screen. The trailered rock screen was designed so that 4-, 3-, and 2-inch material could be retained and weighed separately. All material passing the 2-inch screen was weighed, split, and sacked in the field. The sacked samples weighed on the average 82.2 pounds.

The -2-inch material was dry screened through Gilson vibrating screens in Teichert Aggregates' laboratory. Two of the seven samples were excessively clayey, and special steps were taken to insure that clay balls and adherent clay were not included in 4-mesh material. It was necessary to wash the one-half inch, three-eighths-inch, and the 4-mesh fractions. The -4-mesh material was weighed, split, dried, screened, and tested for sand equivalence and fine durability index according to California Department of Transportation procedure. In performing fine durability and sand equivalence tests, it was necessary to irrigate the samples carefully in order to prevent anomalous results that can occur when working with extremely clayey material. In some cases the tests were repeated four times to insure accurate results (see tables 1 through 8 for the results of this testing).

Many individual tests were performed in the laboratory on samples 101-107 including sodium sulfate soundness, fine aggregate durability, sand equivalent, and concrete compressive strength tests. Only the fine durability and sand equivalence tests are reported in this paper because too few repetitions of the other tests were made to yield meaningful results.

## ESTIMATION OF THE SAND AND GRAVEL RESOURCES OF THE SACRAMENTO AREA

The first step in any mineral resource inventory is to decide what constitutes mineral reserves or resources. A format for computation of reserves should be developed that assures consistent estimates of reserves. In the Sacramento area, three categories of aggregate resources were devised to describe the aggregate deposits.

The first category of aggregate deposits, *permitted reserves,* is probably the most important in a mineral study. Permitted reserves are known quantities of commercial grade aggregate that are legally available for extraction and use. Deposits of known size and quality that have not been "permitted" by local agencies cannot be considered available for mining or inventoried as reserves. The second category of aggregate deposits is *tested resources.* Tested resources are known quantities of commercial grade aggregate that have not been "permitted". The third category of aggregate is *inferred resources.* The inferred resources estimate for this report was made on the basis of inferential geologic and hydrologic data. The inferred resource statement is essentially an estimate of the quantity of aggregate that may be mined in the Sacramento area provided that planning is done to utilize the resource. The estimate is based on the best information available, but should not be used for detailed planning because it is more academic than practical.

Resource estimates are of little value unless the user knows the accuracy of the estimates. Permitted reserve estimates made in this report are probably within 10 to 20 percent of actual tonnages. Tested resource estimates are probably within 15 to 25 percent of true values. The inferred resource estimate is speculative and the accuracy of this estimate depends upon the extent to which the County protects local aggregate deposits from future conflicting land development. Unlike the relatively accurate estimates of tested aggregate deposits, evaluated on the basis of physical parameters, the inferred resource estimate may be in error by as much as 100 million tons. Estimates of sand and gravel resources are necessarily approximate for a number of reasons.

Sacramento County is in the process of formulating a permitting and reclamation policy. For this report a 50-foot setback of pit boundaries from property lines was assumed for the calculation of "buffer" requirement tonnage losses.

The minimum acceptable reserve acreage necessary to amortize a competitive permanent aggregate plant varies with the rated capacity of the plant, and the aggregate "yield" per acre. In Sacramento County, sediments of the Victor Formation have rarely been harvested below the relatively shallow depth of 30 feet. Therefore, approximately 400 acres of reserves are needed to provide sufficient tonnages to amortize a competitive aggregate processing plant.

An undefined variable in the aggregate resource estimates of Sacramento County is the lithologic complexity of some potential aggregate materials. It is uncertain which beneficiation processes would be most effective in producing a usable aggregate from low grade "pit run" materials and how expensive such processes might be when done on a commercial scale. Clearly, if lower grade materials (i.e., Plio-Pleistocene alluvium) can be utilized at a reasonable cost, the volume of known reserves is expanded considerably. Hence, the establishment of a "cutoff" grade is important and somewhat subjective.

According to the best available information, it would cost at least 50 cents per ton more to produce usable aggregate from Plio-Pleistocene rocks than from Victor Formation sediments. The cost would, in fact, likely approach that of producing aggregate from solid rock.

The California Division of Mines and Geology is not entirely satisfied with these estimated reserve tonnages. However, the resource summary shown in table 8 is the most accurate sand and gravel inventory currently available.

Table 1. Aggregate test results SAMPLE NO. 101

| SAMPLE WEIGHTS | | | PERCENTAGE VALUES ADJUSTED TO TOTAL SAMPLE WEIGHT | | |
|---|---|---|---|---|---|
| Screen Size | Weight Retained | Cummulative Weight Retained | Percent Retained | Cummulative Percent Passing | Cummulative Percent Retained |
| 4 Inch | 390 lbs | 390 lbs | 14.9% | 85.1% | 14.9% |
| 3 Inch | 329 lbs | 719 lbs | 12.6% | 72.5% | 27.5% |
| 2 Inch | 472 lbs | 1191 lbs | 18.0% | 54.5% | 45.5% |
| -2 Inch | 1426 lbs | 2617 lbs | | | |
| Minus two inch material (1426 lbs) was split and a sample of (70.2 lbs) was screened as follows. | | | | | |
| 1 1/2 Inch | 15.6 lbs | 15.6 lbs | 12.1% | 42.4% | 57.6% |
| 1 Inch | 9.6 lbs | 25.2 lbs | 7.5% | 34.9% | 65.1% |
| 3/4 Inch | 5.8 lbs | 31.0 lbs | 4.5% | 30.4% | 69.6% |
| 1/2 Inch | 4.0 lbs | 35.0 lbs | 3.1% | 27.3% | 72.7% |
| 3/8 Inch | 3.2 lbs | 38.2 lbs | 2.5% | 24.8% | 75.2% |
| #4 Mesh | 6.2 lbs | 44.4 lbs | 4.8% | 20.0% | 80.0% |
| -#4 Mesh | 25.9 lbs | 70.2 lbs | | | |
| Minus #4 mesh material (25.9 lbs) was split and a sample of (492 grams) was screened as follows. | | | | | |
| #8 Mesh | 90.8 grams | 90.8 grams | 3.7% | 16.3% | 83.7% |
| #16 Mesh | 97.6 grams | 188.4 grams | 4.0% | 12.3% | 87.7% |
| #30 Mesh | 67.3 grams | 255.7 grams | 2.7% | 9.6% | 90.4% |
| #50 Mesh | 38.4 grams | 294.1 grams | 1.6% | 8.0% | 92.0% |
| #100 Mesh | 27.2 grams | 321.3 grams | 1.1% | 6.9% | 93.1% |
| #200 Mesh | 21.2 grams | 342.5 grams | 0.9% | 6.0% | 94.0% |
| PAN | 149.5 grams | 492.0 grams | 6.1% | - | 100.1% |

Sand Equivalent = 19
Durability Index = 25
Total Sample Weight = 2617 lbs

Table 2. Aggregate test results SAMPLE NO. 102

| SAMPLE WEIGHTS | | | PERCENTAGE VALUES ADJUSTED TO TOTAL SAMPLE WEIGHT | | |
|---|---|---|---|---|---|
| Screen Size | Weight Retained | Cummulative Weight Retained | Percent Retained | Cummulative Percent Passing | Cummulative Percent Retained |
| 4 Inch | 69 lbs | 69 lbs | 3.7% | 96.3% | 3.7% |
| 3 Inch | 114 lbs | 183 lbs | 6.1% | 90.2% | 9.8% |
| 2 Inch | 184 lbs | 367 lbs | 9.9% | 80.3% | 19.7% |
| -2 Inch | 1494 lbs | 1861 lbs | | | |
| Minus two inch material (1494 lbs) was split and a sample of (100.8 lbs)was screened as follows. | | | | | |
| 1 1/2 Inch | 8.7 lbs | 8.7 lbs | 6.9% | 73.4% | 26.6% |
| 1 Inch | 14.9 lbs | 23.6 lbs | 11.8% | 61.6% | 38.4% |
| 3/4 Inch | 11.7 lbs | 35.3 lbs | 9.3% | 52.3% | 47.7% |
| 1/2 Inch | 15.8 lbs | 51.1 lbs | 12.6% | 39.7% | 60.3% |
| 3/8 Inch | 11.8 lbs | 62.9 lbs | 9.4% | 30.3% | 69.7% |
| #4 Mesh | 14.6 lbs | 77.5 lbs | 11.7% | 18.6% | 81.4% |
| -#4 Mesh | 23.3 lbs | 100.8 lbs | | | |
| Minus #4 mesh material (23.3 lbs) was split and a sample of (501 grams) was screened as follows. | | | | | |
| #8 Mesh | 110.4 grams | 110.4 grams | 4.1% | 14.5% | 85.5% |
| #16 Mesh | 68.2 grams | 178.6 grams | 2.5% | 12.0% | 88.0% |
| #30 Mesh | 52.8 grams | 231.4 grams | 1.9% | 10.1% | 89.9% |
| #50 Mesh | 47.7 grams | 279.1 grams | 1.8% | 8.3% | 91.7% |
| #100 Mesh | 38.8 grams | 317.9 grams | 1.4% | 6.9% | 93.1% |
| #200 Mesh | 32.3 grams | 350.2 grams | 1.2% | 5.7% | 94.3% |
| PAN | 150.8 grams | 501.0 grams | 5.6% | - | 99.9% |

Sand Equivalent = 21
Durability Index = 27
Total Sample Weight = 1861 lbs

Table 3. Aggregate test results SAMPLE NO. 103

| SAMPLE WEIGHTS | | | PERCENTAGE VALUES ADJUSTED TO TOTAL SAMPLE WEIGHT | | |
|---|---|---|---|---|---|
| Screen Size | Weight Retained | Cummulative Weight Retained | Percent Retained | Cummulative Percent Passing | Cummulative Percent Retained |
| 4 Inch | 288 lbs | 288 lbs | 15.9% | 84.1% | 15.9% |
| 3 Inch | 214 lbs | 502 lbs | 11.8% | 72.3% | 27.7% |
| 2 Inch | 357 lbs | 859 lbs | 19.7% | 52.6% | 47.4% |
| -2 Inch | 950 lbs | 1809 lbs | | | |
| Minus two inch material ( 950 lbs) was split and a sample of (73.0 lbs) was screened as follows. | | | | | |
| 1 1/2 Inch | 11.2 lbs | 11.2 lbs | 8.0% | 44.6% | 55.4% |
| 1 Inch | 10.3 lbs | 21.5 lbs | 7.4% | 37.2% | 62.8% |
| 3/4 Inch | 4.9 lbs | 26.4 lbs | 3.5% | 33.7% | 66.3% |
| 1/2 Inch | 4.6 lbs | 31.0 lbs | 3.3% | 30.3% | 69.6% |
| 3/8 Inch | 2.8 lbs | 33.8 lbs | 2.0% | 28.4% | 71.6% |
| #4 Mesh | 7.4 lbs | 41.2 lbs | 5.3% | 23.1% | 76.9% |
| -#4 Mesh | 31.8 lbs | 73.0 lbs | | | |
| Minus #4 mesh material (31.8 lbs) was split and a sample of (495 grams) was screened as follows. | | | | | |
| #8 Mesh | 86.5 grams | 86.5 grams | 4.0% | 19.1% | 80.9% |
| #16 Mesh | 101.8 grams | 188.3 grams | 4.8% | 14.3% | 85.7% |
| #30 Mesh | 85.8 grams | 274.1 grams | 4.0% | 10.3% | 89.7% |
| #50 Mesh | 48.3 grams | 322.4 grams | 2.3% | 8.0% | 92.0% |
| #100 Mesh | 27.9 grams | 350.3 grams | 1.3% | 6.7% | 93.3% |
| #200 Mesh | 20.4 grams | 370.7 grams | 0.9% | 5.8% | 94.2% |
| PAN | 124.3 grams | 495.0 grams | 5.8% | - | 100.0% |

Sand Equivalent = 22
Durability Index = 24
Total Sample Weight = 1809 lbs

Table 4. Aggregate test results SAMPLE NO. 104

| SAMPLE WEIGHTS | | | PERCENTAGE VALUES ADJUSTED TO TOTAL SAMPLE WEIGHT | | |
|---|---|---|---|---|---|
| Screen Size | Weight Retained | Cummulative Weight Retained | Percent Retained | Cummulative Percent Passing | Cummulative Percent Retained |
| 4 Inch | 236 lbs | 236 lbs | 11.6% | 88.4% | 11.6% |
| 3 Inch | 259 lbs | 495 lbs | 12.7% | 75.7% | 24.3% |
| 2 Inch | 336 lbs | 831 lbs | 16.5% | 59.2% | 40.8% |
| -2 Inch | 1202 lbs | 2033 lbs | | | |
| Minus two inch material ( 1202 lbs) was split and a sample of (87.7 lbs) was screened as follows. | | | | | |
| 1 1/2 Inch | 8.6 lbs | 8.6 lbs | 5.8% | 33.4% | 46.6% |
| 1 Inch | 14.0 lbs | 22.6 lbs | 9.5% | 43.9% | 56.1% |
| 3/4 Inch | 8.0 lbs | 30.6 lbs | 5.4% | 38.5% | 61.5% |
| 1/2 Inch | 8.0 lbs | 38.6 lbs | 5.4% | 33.1% | 66.9% |
| 3/8 Inch | 4.3 lbs | 42.9 lbs | 2.9% | 30.2% | 69.8% |
| #4 Mesh | 8.8 lbs | 51.7 lbs | 5.9% | 24.3% | 75.7% |
| -#4 Mesh | 36.0 lbs | 87.7 lbs | | | |
| Minus #4 mesh material ( 36.0 lbs) was split and a sample of (5029 gms) was screened as follows. | | | | | |
| #8 Mesh | 89.9 grams | 89.9 grams | 4.3% | 20.0% | 80.0% |
| #16 Mesh | 90.7 grams | 180.6 grams | 4.4% | 15.6% | 84.4% |
| #30 Mesh | 92.3 grams | 272.9 grams | 4.5% | 11.1% | 88.9% |
| #50 Mesh | 58.3 grams | 331.2 grams | 2.8% | 8.3% | 91.7% |
| #100 Mesh | 34.9 grams | 366.1 grams | 1.7% | 6.6% | 93.4% |
| #200 Mesh | 26.1 grams | 392.2 grams | 1.3% | 5.3% | 94.7% |
| PAN | 109.8 grams | 502.0 grams | 5.3% | - | 100.0% |

Sand Equivalent = 28
Durability Index = 30
Total Sample Weight = 2033 lbs

Table 5. Aggregate test results SAMPLE NO. 105

| | SAMPLE WEIGHTS | | PERCENTAGE VALUES ADJUSTED TO TOTAL SAMPLE WEIGHT | | |
|---|---|---|---|---|---|
| Screen Size | Weight Retained | Cummulative Weight Retained | Percent Retained | Cummulative Percent Passing | Cummulative Percent Retained |
| 4 Inch | 61 lbs | 61 lbs | 2.7% | 97.3% | 2.7% |
| 3 Inch | 167 lbs | 228 lbs | 7.5% | 89.8% | 10.2% |
| 2 Inch | 227 lbs | 455 lbs | 10.2% | 79.6% | 20.4% |
| -2 Inch | 1759 lbs | 2214 lbs | | | |
| Minus two inch material (1759 lbs) was split and a sample of (93.7 lbs) was screened as follows. | | | | | |
| 1 1/2 Inch | 7.8 lbs | 7.8 lbs | 6.6% | 73.0% | 27.0% |
| 1 Inch | 13.4 lbs | 21.2 lbs | 11.4% | 61.6% | 38.4% |
| 3/4 Inch | 10.5 lbs | 31.7 lbs | 8.9% | 52.7% | 47.3% |
| 1/2 Inch | 13.2 lbs | 44.9 lbs | 11.2% | 41.5% | 58.5% |
| 3/8 Inch | 6.6 lbs | 51.5 lbs | 5.6% | 35.9% | 64.1% |
| #4 Mesh | 8.7 lbs | 60.2 lbs | 7.4% | 28.5% | 71.5% |
| -#4 Mesh | 33.5 lbs | 93.7 lbs | | | |
| Minus #4 mesh material (33.5 lbs) was split and a sample of (517 grams ) was screened as follows. | | | | | |
| #8 Mesh | 69.6 grams | 69.6 grams | 3.8% | 24.7% | 75.3% |
| #16 Mesh | 57.1 grams | 126.7 grams | 3.1% | 21.6% | 78.4% |
| #30 Mesh | 41.7 grams | 168.4 grams | 2.3% | 19.3% | 80.7% |
| #50 Mesh | 36.6 grams | 205.0 grams | 2.0% | 17.3% | 82.7% |
| #100 Mesh | 32.9 grams | 237.9 grams | 1.8% | 15.5% | 84.5% |
| #200 Mesh | 23.9 grams | 261.8 grams | 1.3% | 14.2% | 85.8% |
| PAN | 255.2 grams | 517.0 grams | 14.1% | - | 99.9% |

Sand Equivalent = 10
Durability Index = 20
Total Sample Weight = 2214 lbs

Table 6. Aggregate test results SAMPLE NO. 106

| SAMPLE WEIGHTS | | | PERCENTAGE VALUES ADJUSTED TO TOTAL SAMPLE WEIGHT | | |
|---|---|---|---|---|---|
| Screen Size | Weight Retained | Cummulative Weight Retained | Percent Retained | Cummulative Percent Passing | Cummulative Percent Retained |
| 4 Inch | 341 lbs | 341 lbs | 12.7% | 87.3% | 12.7% |
| 3 Inch | 358 lbs | 699 lbs | 13.3% | 74.0% | 26.0% |
| 2 Inch | 596 lbs | 1295 lbs | 22.1% | 51.9% | 48.1% |
| -2 Inch | 1398 lbs | 2693 lbs | | | |
| Minus two inch material (1398 lbs) was split and a sample of ( 76.9 lbs) was screened as follows. | | | | | |
| 1-1/2 Inch | 12.6 lbs | 12.6 lbs | 8.5% | 43.4% | 56.6% |
| 1 Inch | 17.0 lbs | 29.6 lbs | 11.4% | 32.0% | 68.0% |
| 3/4 Inch | 9.4 lbs | 39.0 lbs | 6.3% | 25.7% | 74.3% |
| 1/2 Inch | 7.1 lbs | 46.1 lbs | 4.8% | 21.0% | 79.0% |
| 3/8 Inch | 3.2 lbs | 49.3 lbs | 2.2% | 18.7% | 81.3% |
| #4 Mesh | 5.2 lbs | 54.5 lbs | 3.5% | 15.2% | 84.8% |
| -#4 Mesh | 22.4 lbs | 76.9 lbs | | | |
| Minus #4 mesh material (22.4 lbs) was split and a sample of ( 514.0 gms) was screened as follows. | | | | | |
| #8 Mesh | 50.9 grams | 50.9 grams | 1.5% | 13.7% | 86.3% |
| #16 Mesh | 58.4 grams | 109.3 grams | 1.7% | 12.0% | 88.0% |
| #30 Mesh | 55.4 grams | 164.7 grams | 1.6% | 10.4% | 89.6% |
| #50 Mesh | 48.5 grams | 213.2 grams | 1.4% | 9.0% | 91.0% |
| #100 Mesh | 42.4 grams | 255.6 grams | 1.2% | 7.8% | 92.2% |
| #200 Mesh | 34.7 grams | 290.3 grams | 1.0% | 6.8% | 93.2% |
| PAN | 223.7 grams | 514.0 grams | 6.6% | - | 99.8% |

Sand Equivalent = 14
Durability Index = 24
Total Sample Weight = 2693 lbs

Table 7. Aggregate test results SAMPLE NO. 107

| | SAMPLE WEIGHTS | | PERCENTAGE VALUES ADJUSTED TO TOTAL SAMPLE WEIGHT | | |
|---|---|---|---|---|---|
| Screen Size | Weight Retained | Cummulative Weight Retained | Percent Retained | Cummulative Percent Passing | Cummulative Percent Retained |
| 4 Inch | 106 lbs | 106 lbs | 4.4% | 95.6% | 4.4% |
| 3 Inch | 78 lbs | 184 lbs | 3.3% | 92.3% | 7.7% |
| 2 Inch | 202 lbs | 386 lbs | 8.5% | 83.8% | 16.2% |
| -2 Inch | 2003 lbs | 2389 lbs | | | |
| Minus two inch material (2003 lbs) was split and a sample of (107.7 lbs.) was screened as follows. | | | | | |
| 1 1/2 Inch | 6.4 lbs | 6.4 lbs | 5.0% | 78.8% | 21.2% |
| 1 Inch | 15.2 lbs | 21.6 lbs | 11.8% | 67.0% | 33.0% |
| 3/4 Inch | 11.8 lbs | 33.4 lbs | 9.2% | 57.8% | 42.2% |
| 1/2 Inch | 17.6 lbs | 51.0 lbs | 13.7% | 44.1% | 55.9% |
| 3/8 Inch | 10.1 lbs | 61.1 lbs | 7.9% | 36.2% | 63.8% |
| #4 Mesh | 17.6 lbs | 78.7 lbs | 13.7% | 22.5% | 77.5% |
| -#4 Mesh | 29.0 lbs | 107.7 lbs | | | |
| Minus #4 mesh material (29.0 lbs) was split and a sample of (492 grams) was screened as follows. | | | | | |
| #8 Mesh | 78.3 grams | 78.3 grams | 3.6% | 18.9% | 81.1% |
| #16 Mesh | 61.3 grams | 139.6 grams | 2.8% | 16.1% | 83.9% |
| #30 Mesh | 52.1 grams | 191.7 grams | 2.4% | 13.7% | 86.3% |
| #50 Mesh | 49.1 grams | 240.8 grams | 2.3% | 11.4% | 88.6% |
| #100 Mesh | 43.2 grams | 284.0 grams | 2.0% | 9.4% | 90.6% |
| #200 Mesh | 31.3 grams | 315.3 grams | 1.4% | 8.0% | 92.0% |
| PAN | 176.7 grams | 492.0 grams | 8.1% | - | 100.1% |

Sand Equivalent = 17
Durability Index = 28
Total Sample Weight = 2389 lbs

Table 8. Sand and gravel resources of the Sacramento area.*

| General location | Estimated usable acreage | Estimated ore thickness | Estimated waste thickness | Approximate tonnage saleable |
|---|---|---|---|---|
| PERMITTED RESERVES | | | | |
| Kiefer area | 538 | 22.8 | 10.9 | 30.7 |
| Perkins area | 89 | 30.0 | 13.0 | 6.7 |
| American River | | | | 1.9 |
| Totals | 630 acres | | | 39.3 million tons |
| TESTED RESOURCES | | | | |
| Sunrise/White Rock/N.E. | 450 acres | 21.0 feet | 8.0 feet | 23.6 million tons |
| Sunrise/White Rock/N.W. | 219 acres | 18.3 | 7.0 | 10.0 |
| Sunrise/White Rock/S.W. | 1269 | 18.1 | 8.0 | 57.5 |
| Perkins area | 368.3 | 24.7 | 20.0 | 22.8 |
| Kiefer area | 633.7 | 24.2 | 12.0 | 38.5 |
| Folsom area | 215 | 20.6 | 7.9 | 11.1 |
| Totals | 3155 acres | | | 163.5 million tons |
| INFERRED RESOURCES | | | | |
| Perkins/Florin area | 3000 acres | 25 feet | 15 feet | 250 million tons |
| Sunrise/White Rock | 180 acres | 21.0 feet | 8.0 feet | 9 million tons |

* Resource estimates were completed in October 1973. Mining has continued since that time at a rate of about 500,000 tons per month.

In summary, as of October 1973, there were less than 40 million tons of permitted aggregate reserves and about 160 million tons of tested resources in the Sacramento area. If steps are taken to secure untested aggregate resource areas for future mining, an additional 260 million tons of aggregate may be proven and used. If historical events are indicative of future developments, portions of the permitted reserve areas and tested resource areas will be lost to conflicting land development.

If Sacramento's population continues to grow as it has in the past five years, then there are probably sufficient permitted reserves to satisfy local demand for at least six years. There are sufficient tested resources to last an additional 20 to 25 years. Around the year 2000, new sources of aggregate will have to be developed unless changes occur in Sacramento's supply and demand relationship. These long-range resources may be found in the untested Florin-Perkins area.

## ECONOMICS OF THE AGGREGATE INDUSTRY IN THE SACRAMENTO AREA

### Demand

Aggregate demand is largely related to activity of the construction industry and therefore is difficult to predict. However, aggregate production has increased steadily over the past 40 years. If historical growth within the industry is indicative of future growth, then Sacramento County aggregate production will increase less than 2 percent annually. Figure 1 shows the apparent sand and gravel production of Sacramento County during the years 1960 to 1973. Production may or may not be equivalent to local demand and consumption. No better indicator is available at this time.

The population of an area bears a direct relationship to the aggregate demand for that area. Per capita consumption of aggregate is dependent upon several factors including the relative activity of the construction industries and the types of construction taking place. The relatively large, fluctuating aggregate demand that developed in the 1960s resulted from an increasing population, the California State Water Project, the Interstate Highway Program, and other governmental construction projects. Most of these projects are being phased out and their termination would normally cause the aggregate demand to decline. However, recent studies indicate that California's population will redistribute geographically and that the Sacramento area will grow faster than other parts of the State. An increase in population and related local construction within the Sacramento area should in part compensate for the general decline in governmentally funded construction projects. The construction of waste water treatment facilities and other public utilities may also result in a temporary increase in aggregate demand.

Sacramento may become a major aggregate source area if the San Francisco Bay Area, the northern San Joaquin Valley, or the Sierra Nevada foothill areas become more deficient in aggregate production capacity and resources.

According to aggregate producers in the Sacramento area, as much as 1 million tons of sand and gravel are exported annually to rural areas and small population centers primarily in the Sierra foothills. The relatively wide distribution of population centers in northern California may necessitate longer haulage distances than might be expected in urban areas inasmuch as gravel plants capable of producing a wide variety of aggregate products cannot operate in areas having low or sporadic demand.

### Production

Approximately 6 million tons of sand and gravel are produced in Sacramento County annually which places the county as the sixth largest producer in California. Approximately 80 percent of this aggregate was used locally. The remainder was shipped to rural areas primarily in the Sierra Nevada foothills.

With existing permitted aggregate reserves and tested resources, the County should be self sufficient with respect to the need for aggregate materials for at least two decades if moderate precautions are taken to prevent preclusive development. Sacramento sand and gravel deposits, however, have historically been deficient in coarse sand and contain excessive amounts of 30-50 mesh sand and oversized cobbles. Aggregate producers annually import about 1 million tons of "pea gravel" and coarse sand from the Cache Creek area. These shipments complicate supply-demand studies because they normally go from one plant to another and the gravel is subsequently distributed from the Perkins plants. Yolo County, therefore, produces far more than would otherwise be indicated by official production statistics. Likewise, actual Sacramento County production is lower than reported. Some of Sacramento County's sand and gravel production has been, in the past, erroneously listed as crushed limestone in U. S. Bureau of Mines statistics. The Bureau is dependent upon voluntary company disclosures of production and they have too few people in the field to check company reports.

Production capacity is as important as aggregate reserves with respect to local aggregate availability. Aggregate production facilities are necessary for beneficiation of "pit run" materials. If there are insufficient facilities to produce enough usable materials, a shortage will develop regardless of the availability of raw materials. The oil refinery capacity problem, which develops during peak periods of fuel oil and gasoline consumption, may be an analogous situation. Sacramento County may suffer a temporary 40 percent production capacity deficiency if Lone Star Industries, Inc., Arden Sand and Gravel Company, and Robertson Sand Company are removed from the American River area in

1975. Teichert Aggregates and Granite Construction Company increased their production in 1974 to partially compensate for a decline in Lone Star Industries' production during that year. It is doubtful that these companies can compensate, on a continuing basis, for the loss of Lone Star, Arden Sand and Gravel, and Robertson Sand and Gravel production.

## Costs and Prices

A fundamental concept in the optimization of mineral resources, especially in regard to the construction minerals, is to utilize the mineral resource in such a way as to derive the maximum benefit at the lowest possible cost. Mining, beneficiation, transportation, and business overhead are cost factors that determine the delivered price of aggregate. Some aggregate "pit run" materials are more costly to mine and process than others, whereas other source materials may be less costly to mine and process, but their location necessitates longer hauls to market areas. In the Sacramento area, the price of aggregate products is lower than in many other northern California areas. The price of a typical aggregate base material, in October 1973, in the Sacramento area was approximately $1.85/ton, F.O.B. plant site. Concrete grade aggregate typically sold for about $2.25/ton.

Tailings from the Folsom-Sacramento dredge field derived from Plio-Pleistocene alluvial terraces cannot be processed economically into aggregate base materials or concrete grade aggregate under present conditions. Five independent contractors and aggregate producers in the Sacramento area, each familiar with aggregate processing and local alluvial deposits, were asked to estimate the cost of producing quality aggregates from Plio-Pleistocene rock. It was estimated that Plio-Pleistocene material might be processed into concrete grade aggregate for no less than $2.75 per ton. The cost might be appreciably higher and equal to that of producing a similar product from solid rock.

Barber-Green Company, a principal supplier of aggregate processing equipment, reported that there are many factors involved in aggregate processing and that superficial judgments should not be used to estimate the costs and types of equipment necessary to beneficiate a particular alluvium. It was also stated that to produce aggregate from Plio-Pleistocene derived tailings would require that a new plant be built and implemented with special crushers, washers, and classifiers. Southern Pacific Milling Company of Santa Maria has been processing low-grade rock material similar to Sacramento Plio-Pleistocene rocks for several years with equipment of this sort. They reportedly are able to produce a State specification grade concrete grade aggregate.

Basalt Rock Company, a major producer from Napa County, produces aggregate base material for $2.85 to 3.25 per ton (November 1973) from solid rock. They do not market concrete aggregate. As was previously stated, in Sacramento County the price for aggregate base material is about $1.85 per ton and State specification concrete aggregate is about $2.25 per ton. The differences in prices between areas is a function of the availability of aggregate resources and beneficiation costs.

Victor Formation alluvium, from which these aggregate products are derived, is the best source currently available in the Sacramento area, exclusive of premium American River gravels, which will reportedly no longer be available for mining as of 1975.

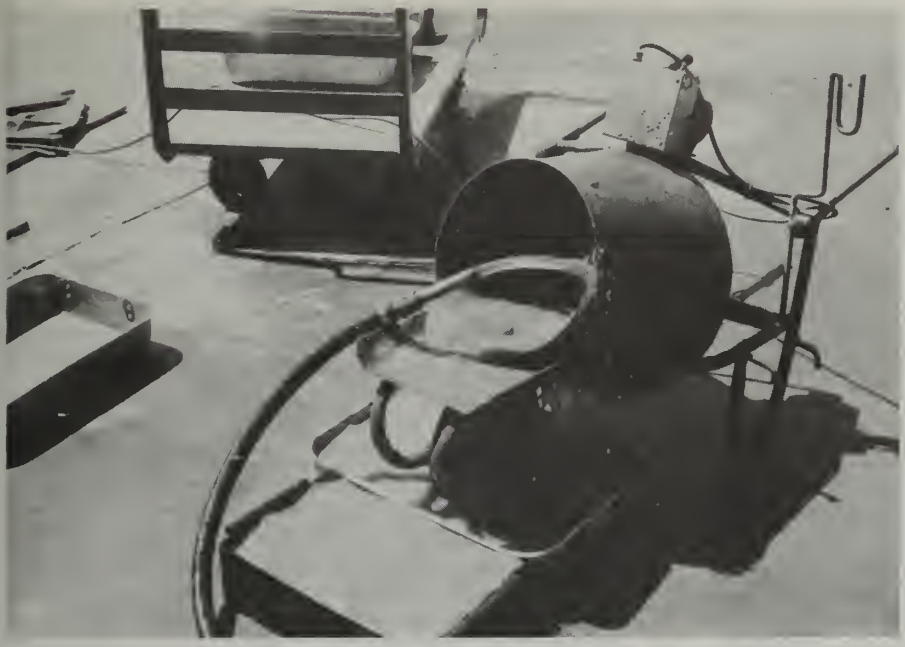
When premium aggregate deposits become exhausted and aggregate prices rise accordingly, there should be a corresponding expansion of what are considered to be economically available reserves. In other words, if the producer has to spend $3.00 per ton to wash, screen, and crush sand, gravel, and rock, a whole new spectrum of potential ore becomes available. Sand and gravel resources must therefore be measured on the basis of relative economic cutoff.

Because of the inherent low value per ton of sand and gravel, the problems of suburban encroachment and waning reserves are also related to transportation costs. Most haulage is done with tandem-trailered trucks. The lowest Public Utilities Commission (PUC) rate for long-haul trucking in the Sacramento and San Joaquin areas is more than 5 cents per ton mile. The nearest gravel deposit to Sacramento, other than the Perkins area, is Cache Creek, near Woodland. In 1973, the PUC haul rate from Woodland to Sacramento was about $2.25/ton. Although some "pea gravels" are imported to supplement Perkins gravel grading deficiencies, a 40-mile haul might be prohibitive in cost on a large scale. Higher fuel costs will undoubtedly force PUC truck rates higher within the next few years.

Industry, through competition and the utilization of more efficient equipment, has kept the cost of aggregate down. However, the optimization of mining and processing equipment has probably reached a plateau and we should expect to see aggregate prices increase at a rate commensurate with general inflation. Three obvious factors that will affect aggregate prices are increasing labor costs, increasing fuel costs, and environmental protection programs.

Figure 14 shows the comparison of the value per ton of sand and gravel sold and used in Sacramento, and the approximate price of carbon steel in the United States. Data on actual aggregate prices were not available for past years. Hence, value per ton was plotted. Unit value of a mineral commodity is closely related to open market prices of that commodity, but not equivalent. Aggregate prices on the open market are always higher than unit values listed in U. S. Bureau of Mines mineral statistics because values per ton are more closely related to the actual cost of production than selling prices. This explains the low values shown on figure 14 and in the Minerals Yearbook of the Bureau of Mines.

Another factor which will tend to elevate consumer aggregate prices is the gradual monopolization of the aggregate industry by large



Photograph 5. Concrete mixer for scrubbing clay-rich aggregate samples. Plio-Pleistocene alluvium was placed in this mixer in order to remove adherent clay. Unsound rock clasts were partially removed by attrition. After processing, concrete test cylinders were made with this Plio-Pleistocene sand and gravel, Type II Portland cement, and the prescribed amount of mix water. A "6 bag" concrete was made and allowed to cure for 28 days. The compressive strength was measured at 1700 psi (pounds per square inch), which is well below State and Federal concrete specifications for strength. An identical concrete made from Victor aggregate measured 4500 psi. The testing was not enough to state absolute conclusions. The implication is that extensive testing would demonstrate that Plio-Pleistocene materials make very low strength concrete.

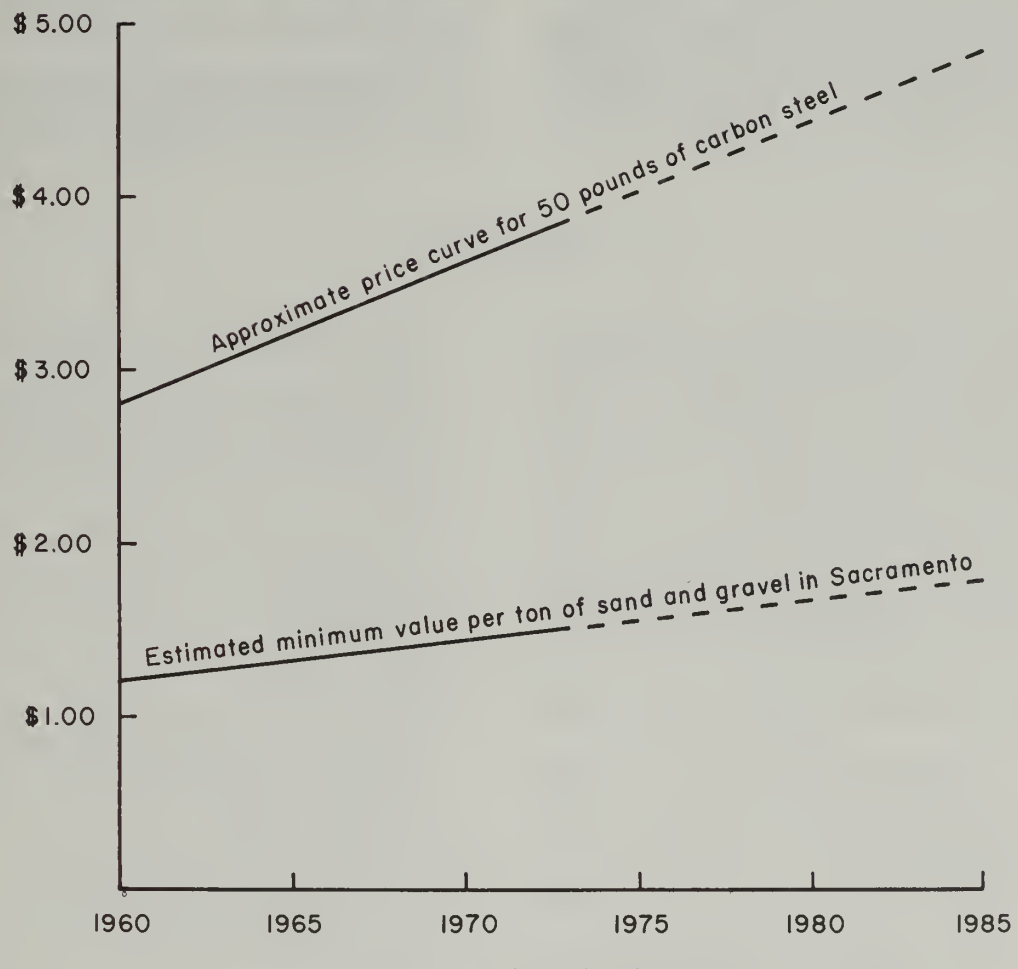



Figure 14. Apparent values per ton of sand and gravel sold or used in Sacramento County and approximate United States carbon steel prices. (Based on statistics from the years 1940-1972 U.S. Bureau of Mines "Minerals yearbooks")

companies. Small aggregate producers which help establish aggregate prices through competition are being phased out. Typically, these small companies lack the sophistication to deal successfully with governmental agencies and, therefore, take the brunt of regulative measures. The smaller aggregate producer generally lacks the capital necessary for extensive plant modifications made necessary by air and water quality regulative measures. In general, they also tend to lack the ability to plan effectively for future reserve depletion. Eventually, northern California contractors and governmental agencies will have only a few large companies from which to buy aggregate. Aggregate prices will be higher.

## SUMMARY AND RECOMMENDATIONS

Sacramento County has about 200 million tons of permitted reserves and tested aggregate resources which should satisfy local demand for the next 25 years. Aggregate resources of the county, exclusive of the deposits of the Cosumnes River area and American River Holocene gravels, are restricted to the Pleistocene Victor Formation. Geographically these deposits exist in the triangular area between the towns of Florin, Perkins, and Folsom (plate 1).

Tailings from the Folsom-Sacramento dredge field were thought for many years to be a readily available source for aggregate materials. However, aggregate and concrete test data indicate that about three-quarters of the tailings are unfit for use in concrete or as aggregate base material. Most of the dredge tailings were derived from Plio-Pleistocene alluvial terraces which typically are sand deficient and contain excessive amounts of clay and cobbles greater than 4 inches in diameter.

Demand for aggregate products will probably increase in the Sacramento area as the population grows. The County has the means to provide for adequate reserves and production capacity. Prices will increase at a rate commensurate with the increase in fuel costs, labor, the extent of environmental enhancement that is required, and the natural escalating effect that occurs when an industry becomes monopolized by a few large companies.

The California Division of Mines and Geology recommends:

1. That the County of Sacramento utilize the concept of multiple-land use to optimize the beneficial use of mineral aggregate resources of the County. Target areas for future mineral development have been delineated in this report.
2. That the County establish a consistent mining policy which incorporates provisions for environmental protection and at the same time allows mining companies to function within the community.
3. That the County do what is necessary to provide adequate aggregate production capacity so as to satisfy future aggregate requirements.

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